JOURNAL OF THE A·I·E·E·

MARCH 1924

PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

American Institute of Electrical Engineers

COMING MEETINGS

Spring Convention, Birmingham, Alabama, April 7-11

Annual Convention, Edgewater Beach, Chicago, Ill., June 23-27

Pacific Coast Convention, Pasadena, Cal., October

MEETINGS OF OTHER SOCIETIES

Southwestern Division, N. E. L. A., New Orleans, La., April 22-25

American Electrochemical Society, Philadelphia, Pa., April 24-26

National Electric Light Association, Atlantic City, N. J., May 19-23

Electric Power Club, Absecon, N. J., May 26-29

The American Society of Mechanical Engineers, Cleveland, Ohio, May 26-29

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OF THE

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Journal of the A. I. E. E.

Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences

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The South as Host to the Institute

A generous share of Southern hospitality is promised all who attend the convention in Birmingham, April 7-11. The technical program presents an interesting and diversified group of papers. Of particular value will be the presentation of practises in various sections of the country which will offer a valuable opportunity for comparison. Water power, transmission and allied subjects will occupy a prominent part of the program and there will be excellent papers on mining applications, metallurgical applications and machine developments.

A special program on the broader phases of power development and interconnection is planned for Tuesday evening. The speakers will be men of national prominence and their addresses will afford valuable information on national power problems.

Birmingham offers many inducements to visiting engineers, situated as it is in the center of coal and iron regions, close to water power sites and tied by transmission lines to one of the longest interconnected systems. Trips are being planned to the interesting places in the neighborhood.

Two country clubs with excellent golf courses will add to the pleasure of visitors and a number of delightful social features are being planned. A genuine Southern barbecue will probably be arranged as an irresistible inducement.

A complete announcement of the convention will be found on page 278.

European Engineering Meetings

The attention of the membership is directed to a more detailed announcement published elsewhere in this issue regarding the various engineering and related meetings to be held in London and on the continent in July of this year.

These various events, and the special transportation arrangements that have been made, offer to American engineers and their families an opportunity to visit England and the continent under unusually favorable conditions from both a professional and a recreational standpoint.

American members who contemplate attending are urged to notify the Secretary of the Institute promptly.

Research Committee Studying Insulation

The study of insulation problems is the subject to which the Research Committee is at present devoting most of its efforts. This committee, it may be pointed out, serves also as an advisory committee on electrical engineering to the National Research Council. In this relationship the Committee has directed its principal attention to questions of electric insulation, and many of its members are also members of the Committee on Electrical Insulation, Engineering Division, National Research Council.

The present outstanding question is as to how the plan for work as announced by the Committee on Insulation can be best furthered and hastened. During the present year chairmen of sub-committees on each of the eight topics listed in the Problem of Insulation as published,* have been appointed, and in addition to this a number of volunteers have been obtained for the work on these sub-committees. The sub-committees plan to make a comprehensive review of all past work done in connection with their several subjects, and the ultimate plan of the Committee on Insulation and the Research Committee of the Institute is to collect and coordinate all of this information in an authoritative review of past work on the subject of insulation, and to outline a plan for further experimental attack leading to a better fundamental knowledge of the phenomena involved in insulation processes.

The Committee has rendered material assistance in the securing of a grant of money from the Hecksher Foundation for experimental work in the field of insulation under the direction of Professor Karapetoff at Cornell University. The Chairman is also acting in an advisory capacity in connection with several other lines of experimental work. The Committee for the present, however, is directing its principal efforts to the review of the literature outline above.

Plans of the Industrial and Domestic Power Committee

The work of the Industrial and Domestic Power Committee this year has consisted largely in investiga-

*Journal A. I. E. E., June, 1923.

tions of specialized equipment and systems for use in a number of industrial fields which at the present time offer wide opportunities for the application of electrical power.

It is the plan of the Committee to secure at least one session per year at an Institute meeting, at which will be presented papers on a particular application coming under the Committee's jurisdiction. In addition, the Committee desires to arrange for several Section meetings, each of these meetings to deal with a type of application that is particularly active in the section of the country where the meeting is held.

Among the numerous applications coming under this Committee the following are those which have been suggested for meetings:

(a) The Sectional Paper Machine Drive.

(b) The Wood Working Industry. This is particularly active in the neighborhood of Seattle and Portland.

(c) Electrical Equipment in Public Buildings.

(d) Electrically Operated Oil Wells, both Drilling and Pumping Features. These applications are especially active in the neighborhood of Los Angeles and in Texas.

(e) The Synchronous Motor for Industrial Drive. This should cover the recent developments in the design of synchronous motors as well as the automatic control suitable for various applications.

One important piece of work done by the Committee was the presentation of two papers on electric elevators at the Midwinter Convention in February. Another contribution was a paper on ventilating fans, presented before the New York Section in November. The Annual Report of the Committee, which is now under preparation covers the subjects outlined above, as well as others, and should be an interesting summary of the progress of the development of industrial and domestic power applications.

Some Leaders of the A. I. E. E.

Norvin Green, the first president of the Institute, was born in New Albany, Ind., April 17, 1818. While he was quite young his family removed to and settled permanently in Kentucky. In the year 1840 he graduated with honor from the Medical Department of the University of Louisville, later being appointed physician in the western Military Academy at Drennan Springs, Ky.

Dr. Green served several terms in the Kentucky legislature, and in 1853 was appointed Commissioner of the United States in charge of the construction of National buildings in Louisville.

While engaged in the duties of this appointment he became one of the trustees of the United Morse and People's Telegraph lines extending between Louisville and New Orleans. Later he was elected president of these interests which were united under the name of the South Western Telegraph Company.

In the year 1866 when the American, United States and Western Union Telegraph lines were consolidated into a single system Dr. Green became vice-president of the enlarged organization, advancing to the position of president on April 22, 1878, where he remained until the time of his death in the year 1892.

He served as the first president of the A. I. E. E., continuing in office throughout the years 1884, 1885 and 1886.

Economies in the Electrification of Ship

The wisdom of the policy of the Shipping Board in promoting the conversion of steam driven cargo vessels to motor ships is illustrated by the fuel economies shown during a 13,329-mile voyage from New York to the Pacific Coast by the motor ship Seekonk recently converted to Diesel drive.

An article in the *Marine Journal* for February 23d shows that the fuel oil consumption per day over the 50 days run was reduced from 29 tons to 7.52 tons.

Of special interest is the saving due to the use of electric drive for the cargo handling and other auxiliaries when in port, the steam auxiliaries requiring before the change 7.5 tons of fuel per day which was reduced by electric auxiliaries to 0.7 ton. The above figures show that practically the same amount of fuel was required in port before conversion as is now required to drive the ship at 10.29 knots, a speed of over a quarter of a knot faster than called for by the original steam equipment.

Aside from the direct fuel saving with the use of electric auxiliaries there will be a material gain from the reduced costs of maintenance of the electric system as compared with a steam system, and in this vessel the change from a steam to an electric system of handling of auxiliaries will be sufficient to pay for the costs of the change in about three years.

Are Engineers too Modest?

In an address by Chairman C. T. Allen of the Western Centre of the British I. E. E. he takes engineers to task for their modesty and lack of self assertiveness in the following language:

"In this connection, a universal defect of engineers is their lack of appreciation of the Press.... The engineer up to the present has been too silently doing his work; but add to his training the art of self-expression, and nothing can prevent him from taking his place at the head of affairs."

The Multiple-Radial System of Cooling Large Turbo-Generators

BY DONALD BRATT

Formerly with Power Engineering Dept., Westinghouse Electric and Mfg. Co.

Review of the Subject.—*The paper discusses the theoretical basis of a special turbo-generator ventilation system, in which the cooling air divides into several branches, and passes through the stator core radially in and out.*

An extended series of experiments on a full-size model, embodying this system, has lately been carried out by the Westinghouse Co. The tests are described in a paper by C. J. Fechheimer under the Title: "Experimental Study of Ventilation of Turbo-Alternators."

The fundamental questions in regard to the flow of air in any ventilation system are:

1. How high pressure is required to force through a certain volume of air per unit time?

2. How will the air distribute, axially and radially, in the different intake and discharge vents?

3. What will be the "balanced state" of flow, if several branches of air meet and divide in a tube, the intake and discharge taking place normal to the walls of the tube?

These questions are given a thorough analysis, under certain simplifying assumptions, and it is shown that

1. The total pressure required for a certain volume of air per unit time is expressible by means of hyperbolic and trigonometric cotangents of a certain argument, which contains the geometrical dimensions of the air-circuit.

2. The air is distributed according to a simple hyperbolic or trigonometric sine-law.

3. The "balanced state" depends on the solution of a system of simultaneous transcendental equations.

A method of solution is outlined, which is applicable for such cases where the arguments are small. In such cases the transcendental equations reduce to simple algebraic equations.

A numerical example is finally worked out in order to show the application of the derived formulas.

Description of System and Statement of Problem

FIGURE 1 illustrates the radial system of ventilation diagrammatically.

The fans $F\ F$ which are attached to the rotor R set up a static pressure in the end-bells $E\ E$. As a result the air, taken in by the fans at $a\ a$, is forced to flow through the system by way of i or g. g is the air gap, i is a duct back of the core, leading to several intake sections I in the core, in which the air travels radially

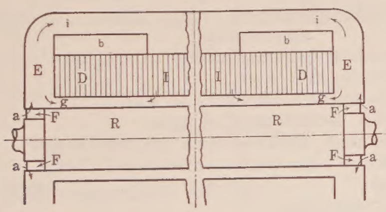


Fig. 1

inwards, dividing in the gap and discharging over the sections D, which are in communication with the external atmosphere at b.

The iron core is assembled as usual in packages, leaving equi-distant vents axially, in which the air alternatively enters and discharges. The arrows indicate the direction of flow.

It is of great importance to know how much air will pass the total system at a given static pressure in the end-bells.

Also, it is necessary to know how the velocity of the air is distributed, as this is of paramount importance relative to the temperature of the iron.

Any attempt to answer these questions exhaustively would necessarily present very great mathematical difficulties. This is particularly evident, as the air in the gap is partly carried along by the rotation of the rotor. It will first of all be necessary, therefore, to neglect the influence of this rotation, which means the same as to assume that the static pressure in the end-bells is furnished by separate external fans. It has been conclusively proved, by actual tests on a full-scale model, that the influence of the rotation on the total volume of air passing is small, and also that the rotation tends to equalize the velocity in the different vents axially. Thus, the temperature in the iron is probably more evenly distributed under running conditions due to the effect of the rotation, so that our assumption errs on "the safe side."

The fundamental law, governing the flow of an

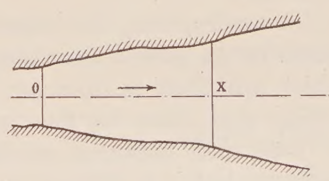


Fig. 2

incompressible fluid is the one first expressed by Bernoulli, stating, that the sum of static head, velocity head and losses, counted from some chosen origin and in the direction of the flow, remains constant. It follows from this, that for any particular circuit $o\ x$ (Fig. 2) we can put the total pressure drop from o to x proportional to the mean air velocity-square at x: the constant of proportionality depending, of course, on x.

Presented at the Midwinter Convention of the A. I. E. E., Philadelphia, Pa., February 4-8, 1924.

Let P = total pressure-drop from o to x
p = static pressure at x
v = velocity at x
γ = density of fluid
g = acceleration of gravity.
then, at any point x we have

$$1.\quad p + \frac{\gamma\, v^2}{2\, g} + \sum_0^x \text{(losses)} = \text{Const.}$$

$$2.\quad P = \sum_0^x \text{losses} = k \times \frac{v^2}{2\, g}$$

The velocity v denotes the volume air per unit time divided by the cross-section at the particular point in question. Hence, no attention is paid to the fact, that the air velocity may vary across the section.

The loss in total head is neglected. Hence, the Bernoulli equation may be written:

$$p + \frac{\gamma\, v^2}{2\, g} = \text{const.}$$

This is necessary in order to obtain reasonably simple results. (Some additional remarks on this particular assumption will be found below).

It is further necessary to assume that the air behaves like an incompressible fluid, that is, that the "principle of continuity" holds.

This is comparatively justified, since the total atmospheric pressure is about 405 in. water, and the total pressure drop in a ventilation-system of this kind rarely would have to exceed 15 in. water, or 3.7 per cent of the total pressure.

The balanced state of flow in a multiple-circuit system will, for its solution, depend on the solution of the air distribution in every particular branch, each branch consisting of one intake and one discharge-length. It is, therefore, necessary to treat one such circuit for itself, assuming the intake- and discharge-lengths etc. to be known, and then to apply the results to the multiple circuit.

This involves the assumption, that there is, between any two air streams in the tube, a closed wall across the tube, against which wall there is, however, no resultant pressure from either side, since the flow is balanced.

It is evident that such balanced points must exist in a multiple system, but it is difficult to say to what extent the conditions would change, (if they changed at all) if partition-walls were actually introduced.

It is, finally, necessary to assume a constant intake and discharge area per unit length of the gap axially, in order to apply the methods of calculus. This fictitious intake and discharge area per unit length is taken equal to the total cross-section area of one vent-circle axially, at the minimum cross-section, divided by the length of one iron package + one radial vent-width axially.

The preliminary problem has now been reduced to that illustrated by Fig. 3. A tube of, say, circular cross-section, closed at both ends, is to a certain length inserted in a pressure-chamber, while the rest of the tube protrudes into the surrounding atmosphere. The tube is perforated, giving a constant intake and discharge area per unit length of the tube.

It is required to determine the total volume of air passing the tube at a given pressure in the chamber, also to determine the law for the air distribution axially.

Assumptions Made to Simplify Problem

It is, perhaps, profitable to summarize the assumptions that have been discussed above.

a. The effect of the rotation is neglected.

b. The variation in air-velocity across the gap, or any other cross-section of the system, is neglected.

c. The loss of head in the gap (or tube) is neglected.

d. The air is incompressible.

e. At any such point in the air gap, where one incoming stream of air divides, or two streams meet, a closed wall is assumed to exist.

f. A uniform intake or discharge-area per unit length of gap axially is substituted for the actual, non-uniform area.

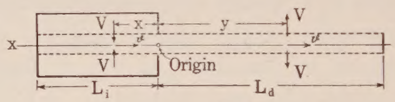


Fig. 3

List of Symbols (Fig. 3).

x = axial coordinate of intake-belt
y = " " " discharge-belt
p = static pressure in tube at x or y
v = axial air-velocity at x or y
V = intake or discharge air-velocity at x or y
a = uniform cross section area of tube
s = uniform intake or discharge area per unit length[1]
P = external pressure (in intake pressure-chamber)
γ = density of air
g = acceleration of gravity

c_i = intake-coefficient, defined by equation $\dfrac{P - p}{\gamma} = c_i \times \dfrac{V^2}{2\, g}$

cd = discharge- " " " " $P/\gamma = cd \times \dfrac{V^2}{2\, g}$

L_i = length of intake-belt
Ld = " " discharge-belt

1. The length-unit will henceforth be taken as one vent-pitch axially.

Note: The constants c_i and c_d deserve special attention. The definition

$$\frac{P - p}{\gamma} = c_i \times \frac{V^2}{2\, g}\ ;\quad P/\gamma = c_d \times \frac{V^2}{2\, g}\ ;$$

means, that the intake air-velocity V can be put proportional to the square-root of the drop in static pressure from the pressure-chamber to the air in the tube, and that the discharge air-velocity likewise can be put proportional to the square-root of the drop in static pressure from the tube to the atmosphere.

The numerical value of c_i and c_d can be determined from the dimensions of the vents in the teeth; the

method of calculation cannot, however, be discussed in this paper.

Derivation of Formulas for Intake and Discharge

a. Intake. Consider the flow along the axis of the tube! By virtue of the assumptions, we must have the sum of the static head and the velocity head constant at all positions:

$$p/\gamma + \frac{v^2}{2g} = \text{const.} \tag{1}$$

But from definition of c_i we have

$$\frac{P-p}{\gamma} = c_i \times \frac{V^2}{2g} \tag{2}$$

So that

$$P/\gamma = P/\gamma - c_i \times \frac{V^2}{2g}$$

Substitute in equation (1), we get

$$P/\gamma - c_i \times \frac{V^2}{2g} + \frac{v^2}{2g} = \text{const.}$$

and by differentiation

$$v\frac{dv}{dx} - c_i V \frac{dV}{dx} = 0 \tag{3}$$

(observing that P/γ and $2g$ are constants.)
In addition to equation (3) we have the obvious condition that the increase in axial velocity over the infinitesimal length dx shall correspond to the air taken in over dx (principle of continuity.)

$$a\,dv = s\,V\,dx$$

or

$$V = a/s \times \frac{dv}{dx} \tag{4}$$

Hence, by differentiation of (4)

$$\frac{dV}{dx} = a/s \times \frac{d^2v}{dx^2}$$

Substitute this expression in (3) then

$$v\frac{dv}{dx} - c_i\,a/s\,\frac{dv}{dx}\,a/s\,\frac{d^2v}{dx^2} = 0;\ \text{or, simpler}$$

$$\frac{d^2v}{dx^2} - \frac{s^2}{a^2c_i} \times v = 0 \tag{5}$$

This equation is linear in v and $\frac{d^2v}{dx^2}$; it has "constant coefficients," and its solution is well-known to be:

$$v = A\,e^{\frac{Sx}{a\sqrt{c_i}}} + B\,e^{-\frac{Sx}{a\sqrt{c_i}}} \tag{6}$$

A and B are the two integration constants to be determined.

Initial conditions:

for $x = 0$ put $v = v_0$

" $x = L_i$ we have $v = 0$

Thus

$$v_0 = A + B$$

$$0 = A\,e^{\frac{SL_i}{a\sqrt{c_i}}} + B\,e^{-\frac{SL_i}{a\sqrt{c_i}}}$$

$$B = v_0 - A;\ 0 = A\,e^{\frac{SL_i}{a\sqrt{c_i}}} + (v_0 - A)\,e^{-\frac{SL_i}{a\sqrt{c_i}}}$$

$$A = -\left(v_0\,e^{-\frac{SL_i}{a\sqrt{c_i}}}\right) : \left(e^{\frac{SL_i}{a\sqrt{c_i}}} - e^{-\frac{SL_i}{a\sqrt{c_i}}}\right)$$

$$B = \left(v_0\,e^{\frac{SL_i}{a\sqrt{c_i}}}\right) : \left(e^{\frac{SL_i}{a\sqrt{c_i}}} - e^{-\frac{SL_i}{a\sqrt{c_i}}}\right)$$

Substituting in (6) thus

$$v = -v_0 \times \frac{e^{-\frac{S(L_i-x)}{a\sqrt{c_i}}}}{e^{\frac{SL_i}{a\sqrt{c_i}}} - e^{-\frac{SL_i}{a\sqrt{c_i}}}} + v_0 \times \frac{e^{\frac{S(L_i-x)}{a\sqrt{c_i}}}}{e^{\frac{SL_i}{a\sqrt{c_i}}} - e^{-\frac{SL_i}{a\sqrt{c_i}}}}$$

which can also be written

$$v = v_0 \times \frac{\sinh\left(\frac{s(L_i-x)}{a\sqrt{c_i}}\right)}{\sinh\left(\frac{sL_i}{a\sqrt{c_i}}\right)} \tag{7}$$

By aid of (4) then, after differentiation of (7)

$$V = v_0/\sqrt{c_i} \times \frac{\cosh\left(\frac{s(L_i-x)}{a\sqrt{c_i}}\right)}{\sinh\left(\frac{sL_i}{a\sqrt{c_i}}\right)} \tag{8}$$

and for the static pressure, by aid of (2)

$$p = P - \gamma \times \frac{v_0^2}{2g} \times \frac{\cosh^2\left(\frac{s(L_i-x)}{a\sqrt{c_i}}\right)}{\sinh^2\left(\frac{sL_i}{a\sqrt{c_i}}\right)} \tag{9}$$

b. Discharge. For the axis of the tube we have again:

$$p/\gamma + \frac{v^2}{2g} = \text{const. (equation 1)}$$

and by definition of c_d

$$p/\gamma = c_d \times \frac{V^2}{2g} \tag{10}$$

Substituting, then

$$c_d \times \frac{V^2}{2g} + \frac{v^2}{2g} = \text{const.}$$

By differentiation

$$c_d \cdot V \frac{dV}{dy} + v \frac{dv}{dy} = 0 \qquad (11)$$

In this case the axial velocity decreases as y increases, hence (compare 4).

$$a\,dv = -s\,V\,dy$$

or

$$V = -a/s \frac{dv}{dy} \qquad (12)$$

By differentiation of (12)

$$\frac{dV}{dy} = -a/s \frac{d^2 v}{dy^2} \qquad (13)$$

Substitute in (11) then

$$c_d\left(-a/s \frac{dv}{dy}\right)\left(-a/s \frac{d^2 v}{dy^2}\right) + v \frac{dv}{dy} = 0$$

or, simpler (compare (5)

$$\frac{d^2 v}{dy^2} + \frac{s^2}{a^2 c_d} \cdot v = 0 \qquad (14)$$

The solution of (14) is well-known to be:

$$v = A \sin\left(\frac{s\,y}{a\sqrt{c_d}}\right) + B \cos\left(\frac{s\,y}{a\sqrt{c_d}}\right) \qquad (15)$$

Initial conditions:

for $y = 0$ put $v = v_0$

" $y = L_d$ we have $v = 0$

Substitute in (15); then

$$v_0 = B; 0 = A \sin\left(\frac{s\,L_d}{a\sqrt{c_d}}\right) + B \cos\left(\frac{S\,L_d}{a\sqrt{c_d}}\right)$$

$$A = -v_0 \frac{\cos\left(\frac{s\,L_d}{a\sqrt{c_d}}\right)}{\sin\left(\frac{s\,L_d}{a\sqrt{c_d}}\right)}; B = v_0$$

Then (15) becomes

$$v = v_0 \times \frac{\cos\left(\frac{s\,L_d}{a\sqrt{c_d}}\right) \times \sin\left(\frac{s\,y}{a\sqrt{c_d}}\right)}{\sin\left(\frac{s\,L_d}{a\sqrt{c_d}}\right)} + v_0 \cos\left(\frac{s\,y}{a\sqrt{c_d}}\right)$$

or, simpler

$$v = v_0 \times \frac{\sin\left(\frac{s\,(L_d - y)}{a\sqrt{c_d}}\right)}{\sin\left(\frac{s\,L_d}{a\sqrt{c_d}}\right)} \qquad (16)$$

and, by aid of (12)

$$V = v_0/\sqrt{c_d} \times \frac{\cos\left(\frac{s\,(L_d - y)}{a\sqrt{c_d}}\right)}{\sin\left(\frac{s\,L_d}{a\sqrt{c_d}}\right)} \qquad (17)$$

Finally, by aid of (10)

$$p = \gamma \times \frac{v_0^2}{2g} \times \frac{\cos^2\left(\frac{s\,(L_d - y)}{a\sqrt{c_d}}\right)}{\sin^2\left(\frac{s\,L_d}{a\sqrt{c_d}}\right)} \qquad (18)$$

If v_0 is the same both for intake and discharge and p has the same value at $x = 0$ and $y = 0$; which is, physically necessary, we may equate (9) and (18) at $x = y = 0$.

thus

$$P/\gamma - \frac{v_0^2}{2g} \coth^2\left(\frac{s\,L_i}{a\sqrt{c_i}}\right) = \frac{v_0^2}{2g} \cot^2\left(\frac{s\,L_d}{a\sqrt{c_d}}\right)$$

or

$$P = \gamma \times \frac{v_0^2}{2g}\left[\coth^2\left(\frac{s\,L_i}{a\sqrt{c_i}}\right) + \cot^2\left(\frac{s\,L_d}{a\sqrt{c_d}}\right)\right] \qquad (19)$$

Equation (19) determines v_0 when P, L_i and L_d are known.

Note. The appearance of trigonometric functions in the formulas for the discharge deserves special attention.

We must have V *positive* for $y = 0$ (meaning discharge) hence it is necessary that $(s\,L_d) : (a\sqrt{c_d}) \leq \pi/2$.

The special case when $\frac{s\,L_d}{a\sqrt{c_d}} = \pi/2$ is particularly interesting. Then

$$v = v_0 \cos\left(\frac{s\,y}{a\sqrt{c_d}}\right); V = v_0/\sqrt{c_d} \sin\left(\frac{s\,y}{a\sqrt{c_d}}\right);$$

$$p = \gamma \frac{v_0^2}{2g} \cos^2\left(\frac{s\,y}{a\sqrt{c_d}}\right)$$

hence for $y = 0$ we have $V = 0$; $p = 0$

" $y = L_d$ " " $V = v_0/\sqrt{c_d}; p = \gamma \cdot \frac{v_0^2}{2g}$

If, therefore, $\dfrac{s\,L_d}{a\,\sqrt{c_d}} > \pi/2$ we will get $V = 0$; $p = 0$ for $y = 0$ *and* V *will remain* $= 0$ until such a y' has been reached, that

$$[s\,(L_d - y')\,] : (a\,\sqrt{c_d}) = \pi/2$$

From now on the static pressure starts to increase and the discharge begins.

It is evident, that the idea of a discharge-tube, where no air escapes except over a certain length adjacent to the closed end of the tube, must be in conflict with

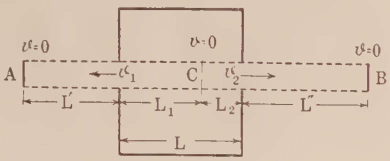


Fig. 4

reality. This is, however, a direct consequence of the assumption that there are no losses of total head in the tube. To overcome such losses a static pressure would always be necessary, resulting in a drop in static head from the tube to the atmosphere, *i. e.*, a discharge would always take place.

A good mechanical analogy is represented by a weight which is pushed over a rough table. The friction makes it necessary to apply a certain force behind the weight, which force would then correspond to the static pressure. If friction was eliminated, the pushing force would drop to zero, and the work represented by the uniform motion of the weight would just equal the work spent to establish the motion, or the work necessary to stop it.

The fundamental equation (1) would strictly have to be written:

$$p/\gamma + \frac{v^2}{2\,g} + \sum_0^x \text{(losses)} = \text{const.}$$

Assuming the losses to be proportional to the square of the axial velocity v and also, for a small length, proportional to that length, we would have

$$\sum_0^x \text{(losses)} = f \times \int_0^x \frac{v^2}{2\,g}\,d\,x$$

where f is a friction coefficient, so that

$$p/\gamma + \frac{v^2}{2\,g} + f \times \int_0^x \frac{v^2}{2\,g}\,.\,d\,x = \text{const.}$$

This equation is evidently much more complicated than (1) and it involves an assumption, which is quite arbitrary, as the law for the losses is not known. It is, therefore, necessary to neglect the losses, that is, to put

$$f \times \int_0^x \frac{v^2}{2\,g}\,d\,x = 0$$

in order to obtain simple results. To correct the error resulting from this approximation, it would be necessary to augment the values of c_i and c_d. These corrections could only be obtained from experiments.

Summary of Formulas

Intake:

$$v = v_0 \times \frac{\sinh\left(\dfrac{s\,(L_i - x)}{a\,\sqrt{c_i}}\right)}{\sinh\left(\dfrac{s\,L_i}{a\,\sqrt{c_i}}\right)}$$

$$V = v_0/\sqrt{c_i} \times \frac{\cosh\left(\dfrac{s\,(L_i - x)}{a\,\sqrt{c_i}}\right)}{\sinh\left(\dfrac{s\,L_i}{a\,\sqrt{c_i}}\right)}$$

$$p = P - \gamma \times \frac{v_0^2}{2\,g}\;\frac{\cosh^2 \dfrac{s\,(L_i - x)}{a\,\sqrt{c_i}}}{\sinh^2 \dfrac{s\,L_i}{a\,\sqrt{c_i}}}$$

Discharge:

$$v = v_0 \times \frac{\sin\left(\dfrac{s\,(L_d - y)}{a\,\sqrt{c_d}}\right)}{\sin\left(\dfrac{s\,L_d}{a\,\sqrt{c_d}}\right)}$$

$$V = v_0/\sqrt{c_d} \times \frac{\cos\left(\dfrac{s\,(L_d - y)}{a\,\sqrt{c_d}}\right)}{\sin\left(\dfrac{s\,L_d}{a\,\sqrt{c_d}}\right)}$$

$$p = \gamma \times \frac{v_0^2}{2\,g} \times \frac{\cos^2\left(\dfrac{s\,(L_d - y)}{a\,\sqrt{c_d}}\right)}{\sin^2\left(\dfrac{s\,L_d}{a\,\sqrt{c_d}}\right)}$$

$$P = \gamma\,.\,\frac{v_0^2}{2\,g}\,.\left[\coth^2\left(\frac{s\,L_i}{a\,\sqrt{c_i}}\right) + \cot^2\left(\frac{s\,L_d}{a\,\sqrt{c_d}}\right)\right]$$

Conditions for Balance in One Intake and One Discharge

If air is taken in over a total length L in a tube similar to the above (Fig. 5) and the discharge condi-

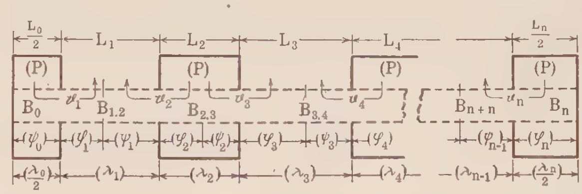


Fig. 5

Note: The quantities ψ, φ and λ are here shown as lengths, but are really dimensionless quantities. This is done to show their relation to the actual lengths L_0 L_1, etc.

tions at A and B are different, for instance so that the discharging ends of the tube are different in length, the question arises: How will the air subdivide between the two halves or, in other words, where is the axial air velocity $= 0$ in the tube?

Notations:

P = total pressure drop
$v_1\,v_2$ = maximum axial air velocities
L = total intake-length axially
$L_1\,L_2$ = intake lengths corresponding to v_1 and v_2
$L'\,L''$ = discharge " " " " " "

Other notations as before.

Consider two separate systems, and a closed wall at $v = 0$ in the intake chamber.

The analytical expression for balance at C is the identity of V at $x = L_1$ and $x = L_2$ (counted from the left and from the right).

By use of equation (**8**) thus:

$$v_1/\sqrt{c_i} \times \frac{1}{\sinh\left(\frac{s\,L_1}{a\,\sqrt{c_i}}\right)} = v_2/\sqrt{c_i} \times \frac{1}{\sinh\left(\frac{s\,L_2}{a\,\sqrt{c_i}}\right)};$$

which immediately gives

$$v_1 : v_2 = \frac{\sinh\left(\frac{s\,L_1}{a\,\sqrt{c_i}}\right)}{\sinh\left(\frac{s\,L_2}{a\,\sqrt{c_i}}\right)}$$

Further, from equation (**19**) applied to the left and to the right

$$P = \frac{\gamma\,v_1^2}{2\,g}\left[\coth^2\left(\frac{s\,L_1}{a\,\sqrt{c_i}}\right) + \cot^2\left(\frac{s\,L'}{a\,\sqrt{c_d}}\right)\right]$$

$$P = \frac{\gamma\,v_2^2}{2\,g}\left[\coth^2\left(\frac{s\,L_2}{a\,\sqrt{c_i}}\right) + \cot^2\left(\frac{s\,L''}{a\,\sqrt{c_d}}\right)\right]$$

Remembering $L_1 + L_2 = L$; we get for L_1 the equation

$$\frac{\coth^2\left(\frac{s\,(L - L_1)}{a\,\sqrt{c_i}}\right) + \cot^2\left(\frac{s\,l''}{a\,\sqrt{c_d}}\right)}{\coth^2\left(\frac{s\,L_1}{a\,\sqrt{c_i}}\right) + \cot^2\left(\frac{s\,L'}{a\,\sqrt{c_d}}\right)} = \frac{\sinh^2\left(\frac{s\,L_1}{a\,\sqrt{c_i}}\right)}{\sinh^2\left(\frac{s\,(L - L_1)}{a\,\sqrt{c_i}}\right)}$$

which must be solved by some cut-and-trial method.

Discussion. For reasons of symmetry we get, when $L' = L'' : L_1 = L_2 = 1/2\,L$. Assume $L' = 0$; then

$$\cot\left(\frac{s\,L'}{a\,\sqrt{c_d}}\right) = \infty$$

and we must have

$$\sinh\left(\frac{s\,L_1}{a\,\sqrt{c_i}}\right) = 0 \text{ or } L_1 = 0$$

Similarly, when $L'' = 0$ we must have $L_2 = 0$ so that, when for instance L' decreases from $L' = L''$ to $L' = 0$, the balance point C will move from $L_1 = 1/2\,L$ towards $L_1 = 0$, and vice versa.

General Multiple Circuit; Statement of Problem

The general problem represented by a multiple-radial system of ventilation is illustrated by Fig. 5.

This is merely an extension of the case treated above, when there are several air-branches in the tube, and hence several balance-points.

It is required to find the location of the balance-points. When these are known, the formulas for distribution of velocity are immediately applicable, and the total volume of air passing the system per unit time can be found.

It must be noted, that a solution of this problem can only be found by some cut-and-trial method, like in all cases, where transcendental functions of the unknown occur. Nevertheless, by simplifications, a sufficiently accurate solution can be obtained, as will be shown below, for certain cases.

List of Additional Necessary Symbols

$\lambda_0/2$ is a fictitious length, corresponding to the drop in pressure, when the air enters from the End-Bell into the gap. (See Numerical Example below).
$L_1\,L_2\,.\,.\,.\,L_n$ are given lengths

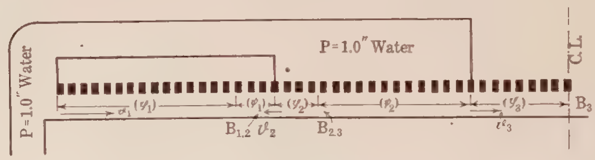


Fig. 6

Note: In regard to the quantities φ and ψ, see note, Fig. 5.

$$\lambda_0/2 = \frac{s\,L_0}{2\,a\,\sqrt{c_i}};\ \lambda_1 = \frac{s\,L_1}{a\,\sqrt{c_d}};\ .\ .\ .\ \lambda_n/2 = \frac{s\,L_n}{2\,a\,\sqrt{c_i}}$$

are thus known, dimension-less quantities.

P = pressure in intake-chambers

$B_{i_1\,(i+1)}$ = balance-points, defined by $v = 0$

$v_1\,v_2\,.\,.\,.\,v_n$ = maximum air velocities axially

$\psi_0\,\varphi_1\,.\,.\,.\,\psi_{n-1}\,\varphi_n$ = unknown dimensionless quantities, determining the location of the balance-points, so that $\psi_0 = \lambda_0/2$; $\varphi_1 + \psi_1 = \lambda$, etc.

Other notations as before.

Establishment of Necessary Equations to Solve General Problem

With above notations, using equations (**8**) and (**17**) as analytical expressions for balance, and equation (**19**) for the total pressure-drop to atmosphere, we get:

$$v_1/\sqrt{c_d}\,.\,\frac{1}{\sin\varphi_1} = v_2/\sqrt{c_d}\,.\,\frac{1}{\sin\psi_1} \qquad P = \frac{\gamma\,v_1^2}{2\,g}\,(\coth^2\psi_0 + \cot^2\varphi_1)$$

$$v_2/\sqrt{c_i}\,.\,\frac{1}{\sinh\varphi_2} \qquad P = \frac{\gamma\,v_2^2}{2\,g}\,(\coth^2\varphi_2$$

$$= v_3/\sqrt{c_i}\ .\ \frac{1}{\sinh \psi_2} \qquad + \cot^2 \psi_1)$$

. . . .

$$v_{n-1}/\sqrt{c_d}\ .\ \frac{1}{\sin \varphi_{n-1}} \qquad P = \frac{\gamma\, v_n^2}{2\, g}\ (\coth^2 \varphi_n$$

$$= v_n/\sqrt{c_d}\ .\ \frac{1}{\sin \psi_{n-1}} \qquad + \cot^2 \psi_{n-1})$$

[$= (n-1)$ equations] [$= n$ equations]

Further $\psi_0 = \lambda_0/2$, $\varphi_1 + \psi_1 = \lambda_1$, $\varphi_2 + \psi_2 = \lambda_2$ . . . $\varphi_n = \lambda_n/2$ [$= (n+1)$ equations]

Unknowns are

$- \psi_0$	v_1
$\varphi_1\ \psi_1$	v_2
$\varphi_2\ \psi_2$	v_3
. . . .	
$\varphi_{n-1}\ \psi_{n-1}$	
$\varphi_n -$ [$= 2\,n$]	v_n [$= n$]

There are $3\,n$ unknowns, and $(n-1) + n + (n+1) = 3\,n$ equations.

The problem is thus fully determined.

Approximate Treatment and Solution

If $\lambda_0/2\ \lambda_1\ \lambda_2$ . . . $\lambda_n/2$ are small enough, we can put $\sin \varphi = \varphi$; $\sinh \varphi = \varphi$; also, therefore, $\cos \varphi = 1$; $\cosh \varphi = 1$ and the equations above will be considerably simplified.

$$v_1/\sqrt{c_d}\ .\ 1/\varphi_1 = v_2/\sqrt{c_d}\ .\ 1/\psi_1 \qquad P = \frac{\gamma\, v_1^2}{2\, g}\ .\ \frac{\psi_0^2 + \varphi_1^2}{\varphi_1^2\, \psi_0^2}$$

$$v_2/\sqrt{c_i}\ .\ 1/\varphi_2 = v_3/\sqrt{c_i}\ .\ 1/\psi_2 \qquad P = \frac{\gamma\, v_2^2}{2\, g}\ .\ \frac{\varphi_2^2 + \psi_1^2}{\varphi_2^2\, \psi_1^2}$$

. . . .

$$v_{n-1}/\sqrt{c_d}\ .\ 1/\varphi_{n-1} = v_n/\sqrt{c_d}\ .\ 1/\psi_{n-1} \qquad P = \frac{\gamma\, v_n^2}{2\, g}\ :\ \frac{\varphi_n^2 + \psi_{n-1}^2}{\varphi_n^2\, \psi_{n-1}^2}$$

$$\psi_0 = \lambda_0/2 \quad \varphi_1 + \psi_1 = \lambda_1 \quad \varphi_2 + \psi_2 = \lambda_2 \ldots \quad \varphi_n = \lambda_n/2$$

Solution:

Remove all the quantities v!

This gives, after some transformation

$$\varphi_1/\psi_0 = \psi_1/\varphi_2 \qquad \text{Put } \psi_0 = \lambda_0/2$$

$$\varphi_2/\psi_1 = \psi_2/\varphi_3 \qquad \psi_1 = \lambda_1 - \varphi_1$$

$$\psi_2 = \lambda_2 - \varphi_2$$

. . . .

$$\varphi_{n-1}/\psi_{n-2} = \psi_{n-1}/\varphi_n \qquad \psi_{n-1} = \lambda_{n-1} - \varphi_{n-1}$$

$$\varphi_n = \lambda_n/2$$

then

$$\frac{2\,\varphi_1}{\lambda_0} = \frac{\lambda_1 - \varphi_1}{\varphi_2}\ ; \qquad \frac{\varphi_2}{\lambda_1 - \varphi_1} = \frac{\lambda_2 - \varphi_2}{\varphi_3}\ ;$$

$$\frac{\varphi_3}{\lambda_2 - \varphi_2} = \frac{\lambda_3 - \varphi_3}{\varphi_4}\ ;$$

$$\frac{\varphi_{n-1}}{\lambda_{n-2} - \varphi_{n-2}} = \frac{2\,(\lambda_{n-1} - \varphi_{n-1})}{\lambda_n}$$

This is a system of $(n-1)$ equations necessary and sufficient to determine the $(n-1)$ unknown quantities $\varphi_1\ \varphi_2\ .\ .\ .\ \varphi_{n-1}$

A numerical example will be treated subsequently.

Numerical Example

Fig. 6 illustrates diagrammatically the arrangement of a ventilation-system in a large turbo-generator.

$C - L$ is the center-line axially, which constitutes a line of symmetry, so that the calculation only has to be carried through for one half of the core.

E is the end-bell: G is the gap. R is the rotor surface.

The notations will be the same as used in 10. There are 84 vents axially, arranged so, that

$L_1 = 18$ vents discharge
$L_2 = 16$ " intake
$L_3 = 16$ " discharge
$L^4 = 16$ " intake
$L^5 = 18$ " discharge

Hence the calculation is performed for

$L_1 = 18$ vents discharge
$L_2 = 16$ " intake
$L_3 = 8$ " discharge

$1/2\, L_0$ is a fictitious intake-length corresponding to the drop in pressure when the air enters the gap from the end-bell.

The value of $1/2\, L_0$ will be determined below from the assumption, that the entrance-drop amounts to 20 per cent of the velocity-head in the gap. This value is found to be a good average for an ordinary-shaped entrance.

a. Value of the constants.

From the dimensions of the machine is directly calculated:

$a = 2.1$ ft.² cross-section of gap, including the sunk parts of the slots.

$s = 0.2$ ft.² per vent-circle, taken at the minimum cross-section of the tooth-vent.

$c_i = 1.30$ and $c_d = 1.07$ are values calculated from the shape of the slots and the teeth, number of teeth and shape of vent-fingers. The details of this calculation cannot be given in this paper.

It must be noted, that c_d and c_i include a correction for the loss in total head which at the present time must be considered as uncertain. This example is, therefore, of value only as far as it illustrates the application of the derived formulas.

b. Value of the arguments.

From definition we get $\lambda_1 = \dfrac{0.2 \times 18}{2.1\,\sqrt{1.07}} = 1.65$;

$$\lambda_2 = \frac{0.2 \times 16}{2.1\,\sqrt{1.30}} = 1.34; \quad \lambda_3/2 = \frac{0.2 \times 8}{2.1\,\sqrt{1.07}}$$

$= 0.73$ is obtained from equation (9) putting $x = 0$, hence

$$P - p = \frac{\gamma\, v_0^2}{2\,g} \coth^2\left(\frac{s\,L_0}{a\,\sqrt{c_i}}\right) = \frac{\gamma\, v_0^2}{2\,g} \coth^2 (\lambda_0/2)$$

The pressure $(P - p)$ has partly been converted into the velocity-head $\frac{\gamma\, v_0^2}{2\,g}$ and partly been destroyed by the resistance at the gap-entrance, which is put equal to 20 per cent of $\frac{\gamma\, v_0^2}{2\,g}$ hence we can also put

$$P - p = \frac{\gamma\, v_0^2}{2\,g} + 0.2\frac{\gamma\, v_0^2}{2\,g} = 1.2\frac{\gamma\, \cdot\, v_0^2}{2\,g}$$

and get for $\lambda_0/2$ the equation

$$1.2\frac{\gamma\, v_0^2}{2\,g} = \frac{\gamma\, v_0^2}{2\,g}\coth^2 (\lambda_0/2)\;;$$

or $\coth^2 (\lambda_0/2) = 1.2$
giving $\lambda_0/2 = 1.53$

This would correspond to a fictitious number of intake-vents L_f where

$$\frac{s\,L_f}{a\,\sqrt{c_i}} = 1.53 \text{ or } \frac{0.2\,L_f}{2.1\,\sqrt{1.30}} = 1.53$$

so that $L_f = 18.3$ vents.

c. Equations for the balance-points.

The simplified equations determining the balance-points can now immediately be written up, *viz.*

$$\varphi_1/1.53 = \frac{1.65 - \varphi_1}{\varphi_2} \qquad \varphi_2 = \frac{1.53\,(1.65 - \varphi_1)}{\varphi_1}$$

$$\frac{\varphi_2}{1.65 - \varphi_1} = \frac{1.34 - \varphi_2}{0.735} \qquad \frac{1.53\,(1.65 - \varphi_1)}{\varphi_1\,(1.65 - \varphi_1)}$$

$$= \frac{1.34 - \dfrac{1.53\,(1.65 - \varphi_1)}{\varphi_1}}{0.735}$$

$$0.735 \times 1.53 = 1.34\,\varphi_1 - 1.53 \times 1.65 + 1.53\,\varphi_1$$

$$\varphi_1 = 3.65/2.87 = 1.27;\text{ hence } \varphi_2 = 0.458$$

To find the number of vents axially corresponding to φ_1 and φ_2 we have

$$\varphi_1 = \frac{s\,L_d}{a\,\sqrt{c_d}} \text{ or } 1.27 = \frac{0.2\,L_d}{2.1\,\sqrt{1.07}}\;;$$

$L_d = 13.8$ vents

$$\varphi_2 = \frac{s\,L_i}{a\,\sqrt{c_i}} \text{ or } 0.458 = \frac{0.2\,L_i}{2.1\,\sqrt{1.30}}\;;$$

$L_i = 5.49$ vents

Note. It is immediately apparent, that the approximate method of solution is *not* applicable in this case, as for instance φ_1 comes out $\varphi_1 = 1.27$.

This is far in excess of the limit, inside which it is admissible to put $\sin\varphi = \varphi$. It will therefore be necessary to apply the original formulas and to find a solution by cut-and-trial.

d. Application of original formulas.

The equations determining the balanced condition are

$$\frac{v_1}{\sin\varphi_1} = \frac{v_2}{\sin\psi_1}\;; \qquad P = \frac{\gamma}{2\,g}\cdot v_1^2\,(\coth^2\psi_0 + \cot^2\varphi_1)$$

$$\frac{v_2}{\sinh\varphi_2} = \frac{v_3}{\sinh\psi_2}\;; \qquad P = \frac{\gamma}{2\,g}\cdot v_2^2\,(\coth^2\varphi_2 + \cot^2\psi_1)$$

$$P = \frac{\gamma}{2\,g}\cdot v_3^2\,(\coth^2\psi_2 + \cot^2\varphi_3)$$

$$\varphi_1 + \psi_1 = \frac{0.2 \times 18}{2.1\,\sqrt{1.07}} = 1.65; \qquad \coth^2\psi_0 = \coth^2\lambda_0/2 = 1.20 \text{ (as before)}$$

$$\varphi_2 + \psi_2 = \frac{0.2 \times 16}{2.1 \times \sqrt{1.30}} = 1.33; \qquad \varphi_3 = \frac{0.2 \times 8}{2.1 \times \sqrt{1.07}} = 0.737$$

The most straight forward method of solution is that of a successive approximation. It is, then, best to start at the $C - L$ and to make some first assumption, say that

1. φ_2 corresponds to 5 vents axially
   ψ_2 " " 11 " "

Thus $\varphi_2 = \dfrac{0.2 \times 5}{2.1\,\sqrt{1.3}} = 0.418$

$$\psi_2 = 1.33 - 0.418 - 0.922$$

and $v_3 = \dfrac{4030}{\sqrt{\coth^2 (0.922) + \cot^2 0.737}}$

$= 2280$ ft./min. [When P is expressed in inches of water and V in feet per minute, the air taken at a density of 0.074 lb./cu. ft. $4030\,\sqrt{P}$ is the value of the constant; it is further assumed here, that $P = 1.''0$ water.]

$$v_2 = v_3 \times \frac{\sinh\varphi_2}{\sinh\psi_2} = 2280 \times \frac{\sinh 0.418}{\sinh 0.922}$$

$= 925$ ft./min.

$$(4030/v_2)^2 = (4030/925)^2 = \coth^2 0.418 + \cot^2\psi_1$$

$$\psi_1 = 0.275$$

$$\varphi_1 = 1.65 - 0.275 = 1.375$$

$$v_1 = v_2 \times \frac{\sin\varphi_1}{\sin\psi_1} = 925\frac{\sin 1.375}{\sin 0.275}$$

$= 3340$ ft./min.

Finally

$$(4030/v_1)^2 = (4030/3340)^2 = \coth^2\psi_0 + \cot^2 1.375;$$

giving the first result $\coth^2\psi_0 = 1.41$.

If assumption 1 had been correct, the final result would have been $\coth^2 \psi_0 = 1.20$.

It is therefore necessary to put

2. $\begin{cases} \varphi_2 \text{ corresponds to } 4 \text{ vents axially} \\ \psi_2 \quad `` \quad `` \; 12 \quad `` \quad `` \end{cases}$

3. $\begin{cases} \varphi_2 \quad `` \quad `` \; 3 \quad `` \quad `` \\ \psi_2 \quad `` \quad `` \; 13 \quad `` \quad `` \end{cases}$

The calculation is eactly the same as before, and the results are given in the table below, also plotted in Fig. 7.

The solution is given on Fig. 7 and corresponds to $\coth^2 \psi_0 = 1.20$.

It is interesting to note, that $(v_1 + v_2 + v_3)$ has a maximum for the balanced condition. This means, of course, nothing else than that the balanced condition is *stable.*

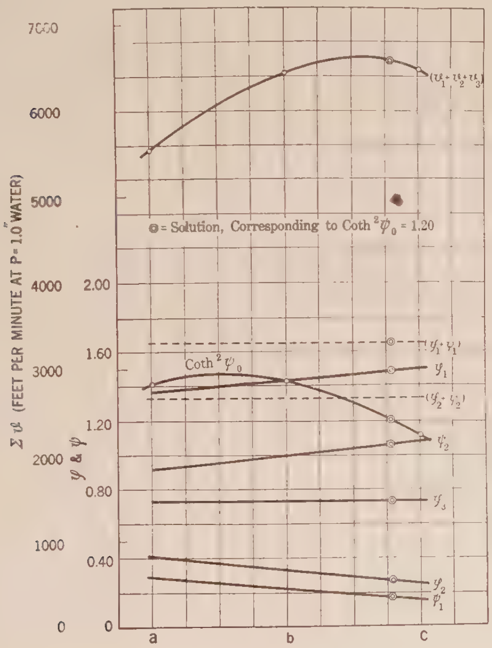


Fig. 7

Table (Fig. 7)

v_1	v_2	v_3	$\Sigma(v)$	φ_3	ψ_2	φ_2	ψ_1	φ_1	$\coth^2 \psi_0$
3340	925	2280	5545	0.735	0.921	0.418	0.275	1.375	1.41
3340	751	2330	6421	0.737	0.996	0.334	0.225	1.425	1.43
3620	463	2400	6483	0.737	1.085	0.251	0.129	1.521	1.11

Discussion

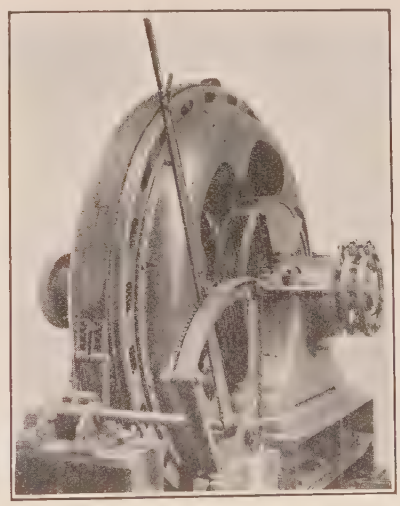
The v-values are those corresponding to $P = 1.''0$ water, and must be multiplied by $\sqrt{P}$ for any other value of P.

The φ- and ψ-values, *i. e.*, the balanced condition, is, of course, independent of P.

It has already been mentioned, that the approximate method fails, in a case like this, to give the solution with any reasonable degree of accuracy. This might have been anticipated from the low resistance at the extreme end ($\coth^2 \psi_0 = 1.20$) resulting in a high value of φ_1.

SUPER SYNCHRONOUS MOTOR

The name "super synchronous" has been given to a certain type of motor, not because the motor operates above synchronous speed but because it has the ability to develop super torque in starting. There has been a demand for a long time for some type of synchronous motor that would develop during the starting cycle a torque as great or greater than that of an induction motor of the wound-rotor, external-resistance type. The first applications of synchronous motors, where considerable starting torque was required, were accomplished by the use of friction clutches. A type of synchronous motor has also been developed, which in its design is quite closely an induction motor but having somewhat larger air gap and a secondary containing a larger amount of copper and wound with reference to the voltage at collector rings required for excitation. Such a motor involves the use of external resistance and changing the connections of the secondary from a polyphase starting net work to a single-phase synchronous field winding. It also inherently has lower efficiency, due to the higher core losses and the greater exciting energy required.



Super Synchronous Motor

The "super synchronous" motor differs mechanically from the ordinary motor in having the stator mounted on auxiliary bearings, which are used only during the starting period, and in having a brake of such proportions as to bring the stator quickly from synchronous speed to rest and to be clamped securely in place. The high starting torque is obtained by virtue of the fact that no torque whatever is exerted on the load until the stator has come to synchronous speed and full excitation has been applied, thus establishing between the stator and rotor the same condition electrically and the same relative peripheral speeds that exist when motor is operating under full load. The torque, therefore, that is available as the rotor speeds up and stator retards, is that of the maximum load torque, or what is often spoken of as "pull-out" torque.

Eddy Current Losses in Armature Conductors

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Review of the Subject.—*This paper is an extension to the author's paper in Vo. XXXIX Pages 997 to 1047 on Eddy Current Losses in Armature Conductors. In this present paper additional formulas are given for the cases where transposed coils are used and also methods given for quickly estimating the increased loss due to eddy currents.*

THIS paper is a supplement to the one presented by the author in the A. I. E. E. JOURNAL, Vol. XXXIX, Part I, for 1920. It is realized that the value of the formula spresented in this type of a paper depends upon their completeness and upon the simplicity of their application. Consequently, additional formulas have been added, covering types of windings neglected in the original paper, and an effort has been made to simplify the application of the formulas. An example has been worked through completely as an illustration.

In the original paper, presented in Vol. XXXIX of the A. I. E. E. TRANSACTIONS, a summary of the results were given between pages 1038 and 1045. This summary covered seven formulas for the calculations of the additional losses in the slot portion of a conductor for different groupings, and an additional formula for the loss outside of the slot portion. These seven formulas were designated A to G, inclusive, and occur on pages 1042 and 1043. They cover the usual winding combinations with coils wound "straight up" and "turned over," as illustrated on page 1012. The short circuits between strands were limited, however, in location. For short circuit occurring at the end of one-half turn, formula B applied. For a short circuit at the end of each full turn, formula D and F applied, and when the short circuit occurred only at the start and finish of the coil, then formulas C, E and G applied. With the above limitations, it is not possible to accurately determine the eddy current losses in a transposed multiple turn coil of the type using two coil sides per slot.

The data in this paper give the formulas necessary to cover this latter case. The nomenclature followed in the original paper will be used in this one, but additional terms will be employed where necessary. These additional terms will be explained at the time they are first used in the text. The formulas only will be given without going into their development which follows the outline previously laid down in detail.

The six formulas necessary to cover all the usual winding combinations with strands short-circuited at one-half turn or each full turn, or at the end of any integral number of full turns, are given below.

When conductors consist of solid bars and there are two coil sides per slot, formula A in Volume XXXIX applies.

When conductors are stranded and the strands are short-circuited at the end of each half turn, and there are two coil sides per slot, formula B in Volume XXXIX applies.

When the coil is wound continuously straight up and there is one coil per slot with a short circuit between strands at the end of ϕ turns, the formula is

$$\text{Ratio} = n^2 \left[\frac{m^2 - 1}{3} + m^2/4 \cos\beta - (m^2/4 + \theta^2/12 - 1/3) \right] M_s + [m^2/4 + \theta^2/12 - 1/3]\, M_c + O_c \quad \textbf{(III)}$$

When the coil is turned over, and there are two coil sides per slot, with a short circuit between strands at the end of turns, the formula is

$$R_t = n^2 \left[\frac{m^2 - 1}{3} + m^2/4 \cos\beta - (m^2/16 + \theta^2/12 - 1/3) \right] M_s + [m^2/16 + \theta^2/12 - 1/3]\, M_c + O_c \quad \textbf{(IV)}$$

$$R_b = n^2 \left[\frac{m^2 - 4}{12} - (m^2/16 + \theta^2/12 - 1/3) \right] M_s + [m^2/16 + \theta^2/12 - 1/3]\, M_c + O_c$$

When the coil is turned over, and there is one coil per slot, with a short circuit between strands at the end of turns, the formula is

$$R = n^2\, [m^2/4]\, M_s + \left[\frac{\theta^2 - 4}{12} \right] M_c + O_c \quad \textbf{(V)}$$

The formula for the loss ratio in the end turns for any of the winding combinations above is given by

$$R = O_c + \frac{n^2 - 1}{n^2} M/r^2\, (K) \quad \textbf{(VI)}$$

The new symbols employed have the following meanings: ϕ is used to designate the number of turns in the coil without a short circuit. In general, this would be the number of turns in the coil as formed in manufacture.

*Deceased

Presented at the Midwinter Convention of the A. I. E. E., Philadelphia, Pa., February 4-8, 1924.

θ is used to designate the number of groups in a transposition. θ can be any integral factor of the slots per pole per phase. m is previously used as the equivalent number of conductors in a slot carrying equal currents. From the definitions above, $m = \phi\,\theta$ for one coil per slot windings, and $m = 2\,\phi\,\theta$ for two coil per slot windings. For example, a two-turn coil for a two-coil per slot winding, if transposed in five groups, would have a value of $m = 20$. A summary of the values given to the other symbols is shown on pages 1040 and 1041 of volume XXXIX.

In formula **VI**, r is used to indicate the ratio of a full turn to the embedded portion. K is used for the coefficient of M_c in that formula which covers the particular winding combination under investigation.

The six formulas give the loss ratios for any usual winding combination for the embedded and end portions of the coils. The most common winding in this country is completely covered by formulas **IV** and **VI**.

In investigating additional losses in armature coils caused by eddy currents, there are two things which it is desirable to know. The more important of the two is the amount of the excess where it has its greatest value. The average value for the entire coil is of secondary importance. The principal purpose of eddy current investigation is to determine the probable temperature rise of the coil. The insulation to ground, or the coil insulation for a 13,200-volt coil is 0.2 of an inch or more in thickness, where mica is used for insulating. The expected temperature drop through such a wall for an average heat dissipation of 0.6 of a watt per square inch would be in the neighborhood of 40 deg. cent. It is obvious, therefore, that any temperature gradient within the wrapper is of secondary importance, and that an average temperature within the wrapper can be assumed without appreciable error. As a consequence, the formulas have been shown indicating the loss ratio for all strands within a ground wrapper.

Formulas **IV** and **VI** cover the great majority of the windings in common use in this country. The application of these formulas appears complicated; in fact, however, it is a relatively simple matter to apply them, provided a preliminary approximation is employed. To illustrate, we will work out an example.

Let it be assumed that it is desired to limit the eddy loss factor in the top coil of a slot to 1.35. Let us assume further that the following conditions obtain. Our winding is to be of the two-coil per slot turned over type. The machine is assumed to be three-phase, four poles, sixty cycles, and to have seventy-two slots. The copper depth total in a slot can be 4.5 inches. The width of copper is 0.5 of an inch and the width of the slot is 1 inch. Assume that the ratio of the coil length to the embedded portion is 2.3. The coils are to be three turns per coil, and are to lie in slots 1 and 15.

The problem is to determine what winding combination will conform to our condition, and limit the loss factor in the top coil to 1.35 when the top coil carries currents in phase with those in the bottom coil. Also, to determine the loss factors for other parts of the coil, as follows: The factor for the top coil, when currents in the bottom coil are 60 degrees out of phase. The factor for the bottom coil and for the ends. And, finally, the factor for the whole winding as a unit.

The preliminary approximation referred to consists in first simplifying formula **IV** and then tabulating the results for different values of m and n. It was shown in the original paper that for small values of $\alpha\,h$ say less than 0.3, that $M_s = \frac{(\alpha\,h)^4}{3}$ and also $M_c = \left[1/n^2 + \frac{n^2-1}{n^2}\,1/r^2\right]\frac{(\alpha\,h)^4}{3}\,n^4$. See TRANSACTIONS, Vol. XXXIX, page 1038. Introducing these values and omitting O_s for the present, we find that formula 4 could be written with $(m\,n\,\alpha\,h)^4$ as a factor. Three new formulas will be written, and their values will give, when added to O_s the loss factor for the top coil side, for the bottom coil side, and for the end portion, respectively. One other change has been introduced in the formulas; that is, since $m\,n\,\alpha\,h$ is a factor, it can be given a definite value, say six and for any change, the incremental loss in excess of O_s will vary as the fourth power of the changed value to six. The simplified equations are

The incremental loss in excess of O_s for a top coil

$$\frac{36}{m^2\,n^2}\left[4 + 3\cos\beta + 1/4\,(3 + 1/\phi^2)\left(\frac{n^2-1}{r^2}\right) - 4/m^2\left(1 + \frac{n^2-1}{r^2}\right)\right] \quad (1)$$

The loss factor in excess of O_s for a bottom coil

$$\frac{36}{m^2\,n^2}\left[1 + 1/4\,(3 + 1/\phi^2)\left(\frac{n^2-1}{r^2}\right) - 4/m^2\left(1 + \frac{n^2-1}{r^2}\right)\right] \quad (2)$$

The loss factor in excess of O_s for the end portion

$$\frac{36}{m^2\,n^2}\left[1/4\,(3 + 1/\phi^2)\left(\frac{n^2-1}{r^2}\right) - 4/m^2\left(1 + \frac{n^2-1}{r^2}\right)\right] \quad (3)$$

In simplifying the equations (**1**), (**2**) and (**3**), above, for our first approximation, it will be noticed that for a value of ϕ equal to 1, the loss increment is a maximum. Also, it will be noticed that if we neglect that term in our equations, which contains m as a factor, that with these two changes the equations are very simply written. It can also be shown that for small values of $n\,\alpha\,h$ that O_s is essentially equal to unity.

With these changes, a table can be given, covering the incremental loss in the top coil under its maximum condition for loss. In this table, the assumption has been made that $r = 2$, and that $\cos \beta = 1$. The table is plotted for various values of m, and for n equal to 1, 2 and 3, respectively.

m	10	12	16	18	20	24	30	36	40	
factor	..	..	0.985	0.776	0.628	0.432	0.280	0.194	0.158	$n=1$
factor	0.690	0.481	0.270	0.222	0.174	0.121	0.078	0.054	0.043	$n=2$
factor	0.355	0.247	0.140	0.110	0.090	0.063	0.040	0.028	0.023	$n=3$

If we consider our problem, and assume that the copper temperature is known, say 100 deg. cent. total, then the calculation of α will be derived as in the previous paper, and would give a value of 1.83. The total copper depth was given as 4.5 inches, and this is equal to $m\,n\,h$. $4.5 \times 1.83 = 8.25$, and the values of the increment of the loss from the tables will be in the ratio of 3.58 for a coil 4.5 inches deep. Consequently, since the limit of the loss in the top coil was to be 1.35, the increment from the table will be 0.098, in order to keep the loss ratio to 1.35. In this connection, it is necessary to remember that there is a manufacturing limitation on the thickness of strands that can be handled; particularly, if mica tape is to be used to insulate the individual strands. A strand of 0.07 inches is about the smallest that can be successfully handled. From our table, therefore, it is evident that m must be 18, and n must be 3, in order to keep the increment approximately 0 098. This gives us a strand of a thickness of 0.0835 inches.

Having derived m and n from the approximation table, their values and the other factors given in our assumptions can be substituted in formulas (**1**), (**2**) and (**3**), for an accurate determination of the various loss factors. There are five factors to be determined: First, the loss in the top coil for $\cos \beta = 1$; Second, the loss in the top coil for $\cos \beta = 0.5$; Third, the loss in the bottom coil; Fourth, the loss in the end portion; and Fifth, the mean factor for the whole winding. These factors can all be determined by substitution in formulas (**1**), (**2**) and (**3**), except the last one, which is a factor of the ratio of the end windings to the embedded portion. The figures are given in the table below:

	Col. 1	Col. 2
Top coil $\cos \beta = 1$ Formula (1)........	0.1005	0.3600 a
" " $\cos \beta = .5$ " (1)........	0.0783	0.2810 b
Bot. coil " (2)........	0.0264	0.0946 c
End portion " (3)........	0.0141	0.0505 d
Factor for entire winding..............		0.1185

Column 2 is obtained from column 1 by multiplying by the factor 3.58. The loss increment for the whole winding can readily be obtained, as it is equal to $3\,a + 3\,b + 6\,c + 15.6\,d$ divided by 27.6. 15.6 is obtained from $(r - 1) \times 2 \times$ coils per pole and phase.

To the above figures in column 2 we have to add the value O_s. It is shown in the original paper how to obtain this value, but an approximation, when $m\,n\,\alpha\,h$ is equal to 6, is given by

$$O_c = 1 + \frac{130}{m^4\,n^2}\left[1 + \frac{N^2 - 1}{r^2}\right]$$

and for any other value of $m\,n\,\alpha\,h$ the increment of loss above unity is to be increased as the fourth power of the ratio of this value to 6. In our case, $O_s = 1.0025$.

It has bèen shown how relatively simple it is to predetermine the loss ratios in the different parts of a turned over two-coil per slot winding with transposition. It is recommended that any one who has occasion to use the approximation frequently will find it most convenient to plot his values on log-log paper. That is, on paper with logarithmic ruling for both ordinates and abscissas. If this method is followed, the table becomes a series of straight lines for different values of n.

One of the purposes in presenting a paper of this kind is to show that designing engineers are fully alive to the importance of theoretical investigations and the necessity of taking into consideration details in design which tend to improve the performance of their apparatus. This paper further illustrates how relatively simple it is to estimate accurately the effect of as complicated a phenomeon as the loss due to eddy currents in a stranded conductor.

A NEW ELECTRIC TELEMETER

The recording of strains produced in bridges by trains or motor trucks passing over them has been made possible by a new electric telemeter or strain gage developed at the Bureau of Standards. The gage has two points which are clamped to the part of the bridge truss on which the measurements are to be made, and two stacks of carbon disks. A change of load on the truss causes a change in the distance between these points, and this is arranged to cause a change in the pressure on the carbon stacks and a consequent change in their resistance. The electrical apparatus can be made to record very rapid changes. The recording apparatus can be used with several gages at once.

The problem of recording these instantaneous strains has never before been successfully solved, although their values were known to be high. A heavy motor truck running over a rough floor, or a locomotive going at high speed, may cause a strain on a bridge truss very much greater than would be caused by the same machine when not in motion. Similar problems occur in the case of aircraft, and the new strain gage can also be used to measure the strains produced in them while in flight. Sixty such gages were used in the tests of the Shenandoah.

This gage is described in Technologic Paper No. 247 of the Bureau of Standards, entitled "A New Electric Telemeter."

Telephone Transformers

BY W. L. CASPER

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Review of the Subject.—*In the communication art transformers are used to transfer inductively the energy of speech currents from one electric circuit to another. In addition to this primary function which must be efficiently performed without distorting the speech significance of the transmitted energy, there is a variety of secondary functions such as making possible the super-position of phantom circuits on ordinary telephone circuits, discriminating between speech and telegraph or signaling frequencies, isolating circuits carrying direct current, and preventing inductive interference between adjacent circuits.*

A discussion is presented of the frequency range over which telephone transformers must operate efficiently in transferring energy between two circuits and the three most common limiting impedance combinations of these circuits, namely, both circuits resistances, one circuit a resistance and the other a positive reactance and one circuit a resistance and the other a negative reactance. The efficiency with which energy is transmitted is measured by comparison with an ideal transformer which is one which introduces no losses and has the best ratio to connect the two circuits. In studying its action the transformer is replaced by its equivalent T network which affords a ready means of analyzing its losses. The variation of the transformer losses with frequency is discussed for the three above mentioned combinations of circuit impedances and characteristic curves are shown for transformers of different mutual impedances. Characteristics are also given showing the operation of the input transformer into the vacuum tube as the mutual impedance and the transformer ratio are varied. The circuit conditions of the input transformer represent a common special case of the third combination of circuit impedances.

The mechanical construction of various transformers is shown, namely, that of the ordinary battery supply repeating coil, of the telephone induction coil, and of three more recent types of transformers used principally in various vacuum tube circuits such as telephone repeaters, carrier frequency and radio circuits. These transformers are all constructed so as to give the desired accuracy of speech transmission under their particular circuit conditions. The climatic conditions present in the widely distributed telephone plant have been carefully considered and the transformers designed to maintain their initial efficiency over a long period of years.

Introduction

The transformers used in the telephone plant are required to transmit speech or signaling currents from one electrical circuit to another in such a way as to obtain maximum transfer of power. They differ in their required action from power transformers in two main respects. They have to transmit milliwatts efficiently instead of kilowatts and must operate efficiently under a variety of conditions of voltage, frequency, etc., instead of under single fixed conditions. These various requirements of operation make it necessary in designing a telephone transformer to proportion it differently from a power transformer.

The requirements of circuits in which telephone transformers are used make it necessary to consider their efficiency in detail over a wide range of frequency and at the same time make sure in each particular case that they have characteristics apart from this efficiency which will enable the circuits to function properly. Such other characteristics, one or more of which may be required of a transformer, are:

1. The efficient transmission of telephone currents while carrying super-posed direct current as in the cord circuit battery supply repeating coil.

2. A high degree of impedance balance between the windings in order: (1) to avoid unbalancing the circuit and rendering it subject to noise or cross-talk troubles; (2) to limit cross-talk in closely associated circuits as in the case of the phantom circuit repeating coil in which the balance required is very precise, the two phantom circuit windings being balanced to about 0.01 per cent; or (3) to prevent sustained oscillations or singing in a two-way telephone repeater as in the case of the repeater output transformer.

3. High efficiency as a low-frequency power transformer, for example, at 16⅔-cycle signaling frequency, as well as high efficiency as a telephone speech frequency transformer.

4. Low efficiency as a power transformer at the frequencies of interruption of direct current used in Morse telegraph as well as high efficiency as an audio frequency transformer. This low power efficiency is necessary in order to reduce troubles, such as, noise interference, false operation of relays and acoustic shock when the same lines are used for both telephone and telegraph.

5. Impedance transformation closely approximating that obtained with an ideal transformer as in the line transformers in circuits in which two-way telephone repeaters are employed. By impedance transformation is meant the modification of the line or network impedances when viewed through the transformer.

6. Impedance transformation for a pair of transformers alike over the transmitted audio frequency range for use as the line and network transformers in two-way repeater operation.

7. Stable impedance transformation even when having been subjected to large magnetizing forces as in the line transformers in two-way telephone repeater circuits in order to maintain the required balance between line and network under all conditions of service.

8. Minimum production of harmonics due to the magnetization characteristics of the iron which would cause interference in the normal transmission frequency range, as in the line transformers on circuits which are used for the transmission of Morse telegraph in addition to speech.

9. To isolate conductively one portion of a circuit from another as in transformers used to connect grounded to metallic lines or to isolate subscriber sets

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from the telephone lines which parallel high-tension power lines and which may therefore be exposed to large inductive disturbances.

10. To maintain the usual conductive isolation and furnish a path to ground for longitudinal currents as may be obtained with a transformer with a shield between primary and secondary windings. By a longitudinal current is meant one which flows along a circuit and returns by some path exterior to that circuit.

As the primary function of the telephone transformer is to transmit telephonic speech efficiently, this paper will be limited to this part of the subject, although the complexity of the telephone plant rarely permits a transformer to be free from the necessity of meeting one or more secondary requirements such as those mentioned above. Two winding transformers only will be discussed.

Frequency Requirements

In the ordinary telephone circuit a range of frequency of about 200 to 2500 cycles is allotted to the transmission of speech, both of these limits varying somewhat with the type of circuit. In the case of long distance lines in which it is desirable to utilize the circuits to the best economic advantage, the frequency range below 3000 cycles is allotted to speech, signaling and telegraph and above that frequency to the transmission of carrier telegraph and telephone. A transformer used for the transmission of speech currents is required to operate efficiently over the entire range of frequency transmitted.

With the present intensive use of the telephone lines, transformers may be required to transmit low-frequency signaling of $16\frac{2}{3}$ or 20 cycles, composite ringing of 135 cycles, speech from 200 to 3000 cycles and carrier from 3000 to 30,000 cycles. This carrier frequency is divided into a number of frequency channels which are used for separate telegraph or telephone circuits. A carrier range from 3000 to 10,000 is generally used for telegraph while with carrier telephone a frequency range from 6000 to 30,000 is used.[1] In certain radio telephone circuits transformers are required to operate at frequencies of the order of 50,000 to 100,000 cycles and in radio frequency amplifiers at approximately 1,000,000 cycles. Telephone transformers may be required to operate at any one of these frequencies or frequency bands or they may be required to transmit efficiently two or more of them. Illustrations of this are the ordinary phantom circuit repeating coil which transmits low-frequency ($16\frac{2}{3}$ cycles) signaling and composite ringing (135 cycles) as well as speech, and the transformers which connect the Key West-Havana cable to the shore lines and which are designed to transmit carrier telegraph up to about 6000 cycles as well as ordinary telephonic speech.

In radio transmitters used for broadcasting and in Public Address Systems[2] where it is desired to transmit music and to reproduce accurately the exact quality of the speaker's voice, it is necessary that any transformers in the circuit operate efficiently at frequencies at least as low as 50 cycles and as high as 5000 cycles.[3]

In the following the operation of transformers over the voice range of frequencies only will be discussed but it is to be noted that the principles involved apply to transformers for carrier and radio frequencies as well.

Impedance Requirements

Another important factor in determining the design and operation of the transformer are the impedances of the circuits which the transformer connects. The circuit impedances, which are the impedances as measured from the place where the transformer is to be located, may be but a few ohms in magnitude or may be several megohms. They may also vary appreciably in magnitude or phase angle over the frequency range.

The circuit impedances met in the telephone plant are seldom either substantially pure resistances or reactances over the entire frequency range and in considering the action of a transformer between two such circuits at any frequency the actual impedances of the circuits at that frequency must be employed. It is impossible to discuss all possible combinations of circuit impedances here. However, with a knowledge of the action of transformers between three limiting combinations of circuit impedances an indication will be given of their operation under all conditions of importance. These three limiting impedance conditions are:

1. Sending and receiving end impedances both resistances.
2. Sending end impedance a resistance, and receiving end impedance a positive reactance.
3. Sending end impedance a resistance, and receiving end impedance a negative reactance.

It is, of course, to be understood that the sending and receiving end impedances may be interchanged. There are, in addition, three other possible limiting circuit impedance conditions—the sending and receiving end impedances both positive or negative reactances and the sending end impedance a positive reactance and the receiving end impedance a negative reactance. These three impedance conditions are less usual than the first three and it is felt to be unnecessary here to discuss in detail the action of telephone transformers in circuits of this type.

Transformer Efficiency

The telephone transformer is generally used for transmission in both directions and the usual definition

1. Colpitts and Blackwell: "Carrier-Current Telephony and Telegraphy," Trans. A. I. E. E., Vol. 40, page 301.

2. Green and Maxfield: "Public Address Systems" Trans. A. I. E. E., Vol. 42, page 247.

3. Fletcher: "The Nature of Speech and Its Interpretation" *Journal* Franklin Institute, Vol. 193, page 729.

Martin and Fletcher: "High Quality Reproduction of Speech and Music" A. I. E. E.—Midwinter Convention, 1924.

in power work for the primary as the winding which receives the energy from the supply circuit does not hold. The terms primary and secondary are therefore used simply to distinguish between the two windings without regard to the energy flow.

It can be shown that maximum power may be delivered from one circuit to another if the impedances of the circuits are equal in magnitude and opposite in phase, that is, if the resistances are equal and if the reactances annul each other. Maximum power may be delivered from one circuit to another in which the reactances annul each other and in which the resistances are not equal provided an ideal or perfect transformer of proper ratio is used to connect the circuit resistances. In the ordinary case it is not possible to annul the reactances over the entire frequency range to be transmitted and no attempt is therefore made to modify them. Under these conditions transformers are used to connect the two circuit impedances and without annuling reactances the greatest amount of power will be delivered by connecting these impedances by means of an ideal transformer of the best ratio.

By an ideal transformer is meant one which neither dissipates nor stores energy. Such a transformer has infinite primary and secondary self-impedances, infinite mutual impedance, unity coupling factor or zero leakage impedances, and zero d-c. resistances. An ideal transformer for any given circuit condition also has the best ratio to connect the circuit impedances.

It may be stated that when the circuit reactances are not annulled by the addition of reactances of the opposite sign, it is possible to deliver more power to the load impedance at certain frequencies by the use of an actual than by an ideal transformer as the transformer impedances may tend to annul the circuit reactances.

It has long been customary in dealing mathematically with a transformer to use in its place some equivalent network such as a π or a T network.[4] The use of an equivalent T network changes a coupled circuit into a simple circuit in such a way as to make it easier to see the effect of changes of the transformer constants on the transmission of the circuit. The equivalent T network of a two-winding transformer is shown in Fig. 1. in which the junction point of the three arms is considered not accessible and in which P, S and M are respectively, the primary, secondary and mutual impedances.

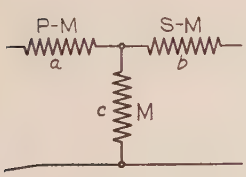

Fig. 1

The series arms a and b of the T network consist respectively of the differences of the primary and mutual impedances and the secondary and mutual impedances. The equivalent T network of the transformer is sometimes shown having series arms $P + M$ and $S + M$ and shunt arm $- M$. These two T's may be derived from the transformer impedances depending on whether the secondary is connected to give a received current in one direction or the other. The T shown here is the most convenient for ordinary considerations. Considering for the present a unity ratio transformer, the arm a will contain the d-c. resistance of the primary and the arm b the d-c. resistance of the secondary. In addition, the leakage impedance will be divided between them. Whether the leakage impedance should properly be considered principally in the arm a or principally in the arm b or divided equally between them depends on the relative location of the primary and secondary windings. However, in the ordinary case the coupling factor is so near unity and the leakage impedance is so small in comparison with the primary, mutual and secondary impedances that practically no error is introduced if it is assumed to be divided equally between them.

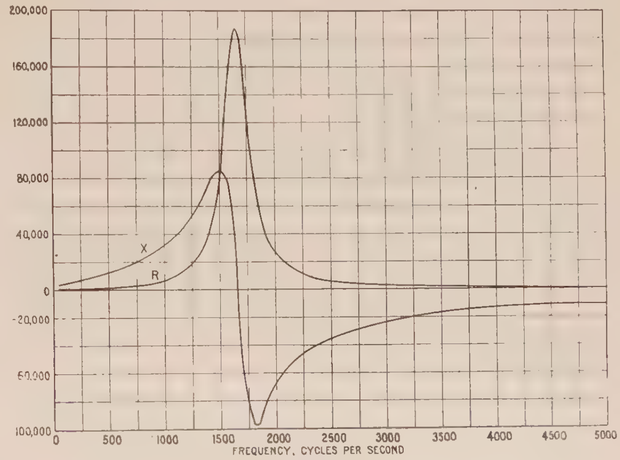

Fig. 2—Mutual Impedance M of a Phantom Circuit Repeating Coil
X Effective reactance—ohms
R Effective resistance—ohms

The shunt arm c of the equivalent T network contains the mutual impedance M. This mutual impedance equals $K \sqrt{P_0 S_0}$ where P_0 and S_0 are the primary and secondary impedances less their respective d-c. resistances, and where K is the coupling factor. The coupling factor K has a phase angle in actual transformers but where the coupling factor is nearly unity the angle may usually be disregarded. The mutual impedance is a complex quantity as are also the primary and secondary impedances of all usual transformers. As the mutual impedance is dependent on P_0 and S_0, any factors which enter into P_0 and S_0 will also enter into M. The reactance components of these impedances depend on the number and distribution of turns in the windings and the dimensions and permeability of the core. The resistance component is made up of an effective resistance due to hysteresis, eddy current and dielectric losses.

The distributed or lumped capacities of the windings are best considered in their effective values. These

4. Campbell: "Cissoidal Oscillation" Trans. A. I. E. E., Vol. 30, Part 2, page 873.

effective capacities may be regarded as shunted across the primary or secondary of the transformer or may be considered as located across M of the arm c of the equivalent T of the transformer. If this effective capacity is considered in shunt with M and combined in it, both the resistance and the reactance of M will have components due to the effect of this capacity. The effective resistance and effective reactance of M will then go through the usual curves for parallel resonance as shown in Fig. 2 for a typical phantom circuit repeating coil.

One other factor frequently enters into the determination of the effective value of M as well as P_0 and S_0. In some circuits, in order to economize on the amount of apparatus necessary, a direct current is allowed to flow through the primary or secondary windings of the transformer. This causes a uni-directional magnetizing force in the core in addition to the a-c. magnetizing force of the speech current. This d-c. magnetization causes a decrease in M from the initial value or value with no d-c. magnetization, depending upon the strength of this magnetization and the reluctance of the magnetic circuit.

The series arms of the equivalent T of the unity ratio transformer are thus impedances consisting of the d-c. resistances and the leakage impedances and are usually relatively small compared with the circuit impedances while the shunt arm is the mutual impedance which is usually large compared with the circuit impedances. The simplicity of the equivalent T network of the unity ratio transformer is very useful and convenient in studying the effect of the transformer in producing losses. With an inequality ratio transformer, however, the arms a and b which equal $P-M$ and $S-M$, respectively, do not appear as small impedances. For instance, if P is larger than S, $P-M$ will be a large positive impedance and $S-M$ will be a large negative impedance and the T network has no decided advantage, from a mathematical standpoint over the ordinary transformer network.

Fig. 3 shows a transformer operating between the sending end impedance Z_1 and receiving end impedance Z_2. Z_2 may be considered less than Z_1. The actual sending and receiving circuits in telephone work are usually quite complex, each consisting of numerous series and shunt elements. According to Thévenins theorem[5] any electromotive force acting through any circuit no matter how complex will produce the same current in any receiving impedance as will some other electromotive force bearing a definite relation to the first electromotive force and acting directly in series with the impedance which would be obtained by a measurement of the circuit looking away from the terminals from which the receiving circuit has been disconnected. From this theorem it may be shown that the complex sending and receiving circuits may be replaced respectively by simple series impedances Z_1 and Z_2 which are the impedances of the complex sending and receiving circuits looking away from the place where it is desired to join them, and a transformer or any other structure studied between these impedances will act identically as if connected between the more complex actual circuits.

5. Comptes Rendus for 1883, Vol. 97, page 159.

If the transformer shown in Fig. 3 were the ideal transformer to connect the circuit impedances Z_1 and Z_2, the best impedance ratio could be found as follows: The current received through the impedance Z_2 is

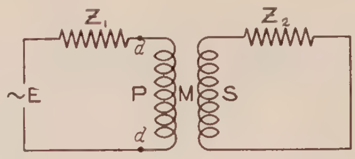

Fig. 3

$$I = \frac{E\,M}{(Z_1 + P)\,(Z_2 + S) - M^2}$$

But since in the ideal transformer P, S and M are infinite pure reactances and the coupling factor is unity and $M = \sqrt{P\,S}$

$$I = \frac{E\,M}{Z_1\,S + Z_2\,P}$$

This expression may be shown to be a maximum when the ratio P/S is equal to the absolute magnitude of Z_1 / Z_2.

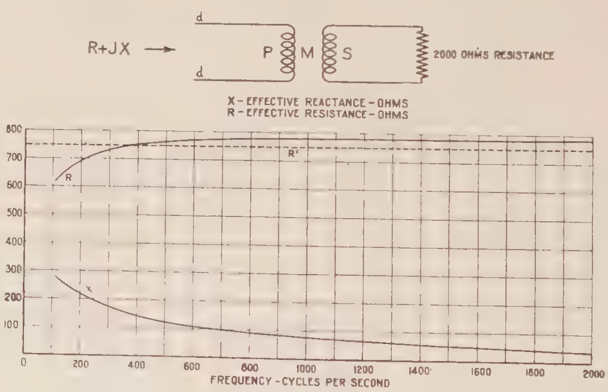

Fig. 4—Impedance Measured at *d-d* Ratio of Impedances P:S = 1:2.66

A transformer designed for the circuit of Fig. 3 should, therefore, have an impedance ratio $R = P/S = Z_1/Z_2$. With an ideal transformer of such a ratio the impedance at d, d looking toward the receiving end with the sending end open at d, d will equal Z_1. Such an impedance characteristic as measured with an actual inequality ratio transformer having an impedance ratio of 1:2.66 and a receiving end impedance Z_2 of 2000 ohms non-inductive resistance is shown as $R+j\,X$ in Fig. 4. The corresponding characteristic for an ideal transformer of the same ratio is shown as R^1. These characteristics show that an actual transformer in transforming for

modifying the circuit impedance adds both a resistance and a reactance component to the value of the circuit impedance divided by the transformer impedance ratio except at low frequencies where the transformer has a considerable shunting effect on the circuit impedance as explained later on, and where the resistance falls below the value obtained with an ideal transformer and the reactance is increased over its value at higher frequencies.

It may be stated that under certain circuit conditions it is quite important that the transformer give a transformation of the circuit impedance which is nearly ideal in order to limit the impedance irregularity introduced in the line.

For analysis or design work involving inequality ratio transformers the circuit of Fig. 3 may be reduced to a circuit in which the impedances Z_1 and Z_2 have the same absolute magnitude and the equivalent T network of the transformer may be reduced to an equivalent T of an equivalent unity ratio transformer. In this way the disadvantages of the equivalent T network of the inequality ratio transformer are avoided. This transformation is made by multiplying the circuit impedance Z_2 and the secondary impedance S by the impedance ratio R and multiplying the mutual impedance M of the transformer by $\sqrt{R}$ as shown in Fig. 5. As $P_0 = M \sqrt{R} / K$, $P - M \sqrt{R}$ will be a small positive quantity, and as $S_0 = M/K \sqrt{R}$, $S R - M \sqrt{R}$ will be a small positive quantity. $M \sqrt{R}$ will be a large positive quantity. This treatment of the transformer presupposes that P_0 and S_0 have the same phase angle. This is not necessarily precise in the case of all transformers but will hold with sufficient accuracy for the usual type of iron core transformers.

The series arms a and b and the shunt arm c of the equivalent unity ratio T network consist respectively of the d-c. resistances of the primary and secondary plus the leakage impedance, and the mutual impedance, all reduced to terms of the sending end impedance Z_1. In this transformation a circuit such as is shown in Fig. 3 is changed to an equivalent circuit as shown in Fig. 5. This equivalent circuit gives a received current which is less than the received current of the circuit of Fig. 3 by the factor $I/\sqrt{R}$ but the received power is the same in each case. This equivalent T of the equivalent unity ratio transformer consisting of relatively small impedances in series with the circuit and a relatively high impedance as a shunt across the circuit, furnishes an easy means of studying the losses produced by a transformer.

The telephone engineer as well as the power engineer is concerned with the delivery of power. In power work the efficiency of a device is usually expressed in per cent as the ratio of the power delivered to the power supplied or the watts output divided by the watts input. In telephone work it is customary to consider the losses caused by the device rather than its efficiency. These losses are determined by the change in received power caused by the insertion of the device in the circuit. They are expressed in terms of the attenuation of a length (in miles) of standard cable ($M. S. C.$). This unit is such that if two currents I_1 and I_2 flow through the same impedance (load) delivering powers W_1 and W_2 respectively, the number of miles corresponding to the current or power ratios is given by the relation $M S C = 21.12 \log_{10} I_1 / I_2 = 10.56 \log_{10} W_1 / W_2$. It can be shown from the above that for small losses a change in current ratio of 1 per cent corresponds approximately to 0.1 mile of standard cable.

In inserting an ideal transformer of best ratio between two circuits of different impedance an increased current is obtained through the receiving end impedance and a transmission gain is effected. If an actual transformer were used in place of the ideal transformer a somewhat lesser gain would usually be obtained due to the losses of the transformer. The transformer loss is determined by the ratio of the received current with the transformer in circuit to the received current with the ideal transformer in circuit.

It is to be noted that the above mentioned ratio of received currents which is used as the basis of the transmission loss of the telephone transformer takes no account of the phase angle of the load impedance and bears no direct relation to the ratio of the power output to the power input. There is, therefore, no very simple relation between the miles loss and the power efficiency. For example, a telephone transformer might have equally low losses when operating into a pure reactance as when operating into a resistance, whereas, the power efficiency approaches zero when the phase angle of the load approaches 90 deg. When operating into a resistance load the current ratio of the telephone transformer approaches the square root of the power efficiency for very efficient transformers.

Transformer Operating Between Resistances

From the circuit of Fig. 5, it can easily be seen that provided the circuit impedances approximate resistances, the smaller $P - M \sqrt{R}$ and $S R - M \sqrt{R}$ are and the larger $M \sqrt{R}$ is, the smaller will be the loss caused by the transformer. The speech current used in most telephone circuits is so minute that the permeability of the transformer cores remains at approximately its initial value regardless of what winding is placed on the transformer. An increase in the mutual impedance will lower the shunt losses, but will also cause an increase in the series losses, as there will be an increase in the d-c. resistance and the leakage impedance in practically the same ratio as the increase in the mutual impedance. If the capacity in the transformer windings is neglected, it will be noted that both the series and shunt arms of the

transformer T contain components of impedances which increase with the frequency and that at zero frequency the shunt loss will be infinitely great and at infinite frequency the series loss will be infinitely great while at intermediate frequencies these losses will be finite. It is, therefore, evident that for a given transformer there will be some frequency at which the transformer operates with minimum losses, and that for operation at a given frequency there is a value of mutual impedance for any given transformer structure at which the losses are a minimum.

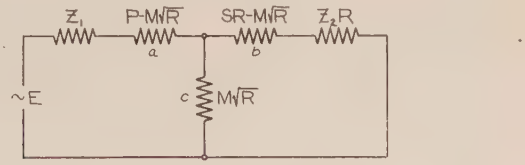

FIG. 5

The transformer of Fig. 5 when operating between non-inductive resistance impedances will produce a loss-frequency characteristic, as shown in Fig. 6, in which the various curves are for a fixed circuit condition and for several different windings or values of mutual impedance. In these characteristics the d-c. resistance of the winding produces a loss which is practically independent of frequency. There is an increase in loss at the lower part of the frequency range due to the increased shunting effect of $M\sqrt{R}$ at the lower frequencies. This loss decreases as the frequency

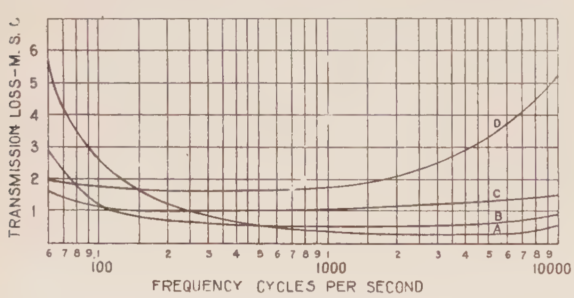

FIG. 6—TRANSFORMER OPERATING BETWEEN RESISTANCES

Sending end resistance 6000 ohms
Receiving end resistance 2000 ohms

Transformer	$\frac{M\sqrt{R}}{Z_1}$ at 1000 cycles
A	5
B	10
C	20
D	40

increases. Although in any actual case the departure of the angle of $M\sqrt{R}$ from 90 deg. may cause an appreciable part of the shunting loss it is usually possible to obtain greater reduction in loss by increasing the absolute magnitude of this impedance than by increasing the phase angle. If the transformer has sufficient capacity in and between the windings to affect appreciably this impedance, it may also affect the loss due to it. In some transformers, the effective capacity may be large enough to cause resonance within the frequency range which is transmitted efficiently. This would cause $M\sqrt{R}$ to have a maximum value at the resonance frequency, and the loss due to the shunt arm would go through a minimum value at this frequency. If the capacity is large enough to produce this resonance near the lower end of the transmited frequency range, its effect at the higher frequencies in decreasing the magnitude of $M\sqrt{R}$ might be sufficient to cause an appreciable loss at these frequencies.

The magnitude of the leakage impedances, which, together with the d-c. resistance, make up the series arms of the T, also tends to increase the loss at the upper frequencies, as this impedance increases with the frequency. In cases where both the leakage and the capacity are high, the effect of one may to some extent tend to lessen the loss produced by the other at some frequencies.

It is to be noted that as the leakage impedance generally consists of a larger reactance than effective resistance, this impedance has far less effect in determining the value of received current through Z_2 when the circuit impedances are resistances than does the d-c. resistance.

In the design of telephone transformers to operate with little distortion between resistance impedances, it follows that the transformer impedance ratio is determined as the ratio of the circuit impedances between which the transformer operates, the loss at the lower frequencies is determined principally by the impedance of the shunt arm of the T network, $M\sqrt{R}$, and the loss at the higher frequencies is determined principally by the leakage impedance and the effective capacity. The d-c. resistance adds a loss which is practically constant over the frequency range.

The determination of the windings of such a transformer would be made as follows, assuming for the present that the transformer construction has already been decided upon. The impedance ratio of the transformer is calculated as the ratio of the circuit impedances. Using this ratio, the winding is calculated, choosing such sizes of wire as will make the ratio of d-c. resistance of primary and secondary the same as the impedance ratio, and will completely fill the winding space with an allowance for commercial variations in the winding space, dimensions, wire diameter, winding and insulation. As the transformer dimensions and core permeability (initial or low magnetic density value) are known, the inductance for a given number of turns may be calculated as proportional to the square of the turns or from a trial winding the relation between impedance and number of turns may be obtained. The coupling factor and effective capacity are best obtained by a trial design using the arrangement of winding which is expected to be used in the final design. All the information for determining equivalent T networks is thus available.

The loss curves for different values of mutual impedance may be predetermined from these equivalent networks and the desired winding chosen from these characteristics. Such a series of curves for a transformer operating between resistance impedances is shown in Fig. 6. In the table in this figure is shown the ratio of the shunt arm, $M\sqrt{R}$, of the equivalent T network of the equivalent unity ratio transformer at 1000 cycles, to the sending end impedance Z_1.

Fig. 7 shows the transmission loss characteristic of

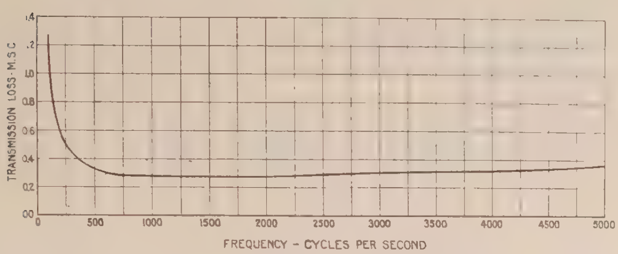

Fig. 7—Transmission Loss Characteristic of Phantom Circuit Repeating Coil Operating between 1830-ohm Resistance Lines

a phantom circuit repeating coil operating between non-inductive resistance lines of 1830 ohms. The mutual impedance-frequency characteristic of this repeating coil was shown in Fig. 2 from which it may be noted that the reactance component of this impedance is negative above a frequency of 1700 cycles per second. Although above this frequency the mutual impedance decreases, its magnitude is so great as compared with that of the line impedance that the loss due to it is practically negligible at a frequency of 5000 cycles per second.

Transformer Operating Between a Resistance and a Positive Reactance

The case of a transformer operating into a pure positive reactance is, of course, hypothetical and no energy would be delivered unless the reactance had a resistance associated with it. In any actual case, there is always a resistance component to this impedance, but for this discussion it is assumed that the resistance component is practically zero.

In this circuit condition we have one impedance which is independent of the frequency and another which is directly proportional to the frequency, By properly choosing the transformer ratio it is possible to match the circuit impedances at any particular frequency and deliver maximum energy at this frequency. At other frequencies there would be a transmission loss due to this failure to match impedances, and it follows that even with an ideal transformer, it is not possible to obtain uniform efficiency over a range of frequency, and that by selecting the proper ratio, maximum efficiency may be ontained at any desired frequency.

Fig. 8, curve A, shows the transmission loss, in miles due to the introduction of an ideal transformer of fixed ratio between the sending end resistance Z_1 and the receiving end reactance Z_2. This transformer serves to match these impedances at the frequency F_1 and the curve shows the loss above what would be obtained if the impedances were matched at any other frequency. Curve B is a similar characteristic for an ideal transformer, matching impedances at frequency F_2.

Fig. 5 may be considered to represent the equivalent unity ratio circuit (Z_2 being less than Z_1) with the T network of the equivalent unity ratio transformer in the circuit. If, for the present the effect of capacity in the mutual impedance is neglected, the losses produced by the components of the series arms of the transformer operating under these circuit conditions, that is the d-c. resistance and the leakage reactance, are approximately of equal importance. The d-c. resistance causes a loss which is finite at low frequencies and decreases to zero at infinite frequency while the leakage reactance causes a loss which is finite at infinite frequency and reduces to zero at zero frequency. The mutual impedance produces a loss which is infinite at zero frequency and decreases to a relatively small finite value at infinite frequency.

If the mutual impedance contains a capacity component, a reduction of loss may be produced at certain frequencies due to resonance of the capacity reactance with the mutual, leakage and receiving end reactances. This may even give a gain over the characteristic of the ideal transformer for a limited frequency range, but

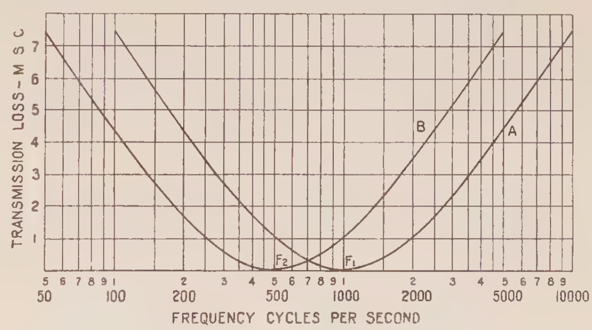

Fig. 8—Transformer Connecting a Resistance to a Positive Resistance

"A" and "B" ideal transformers of Impedance ratio R/X at frequency "F_1" and "F_2" respectively.

above the resonant frequency an increased loss is produced which approaches infinity.

Characteristics A, B, C and D of Fig. 9 show measurements of actual transformers having different values of mutual impedance and the proper ratio to match impedances at 1000 cycles. The transmission losses shown are the losses of the actual transformers compared with the corresponding ideal transformer of the same ratio. The ideal transformer, itself, has a loss characteristic causing distortion which varies with the frequency as shown in Fig. 8. The ratio of

$M\sqrt{R}:Z_1$ at 1000 cycles is shown in the table. These transformers are the same as those shown in Fig. 6 as operating between resistances. The losses at the upper frequencies are reduced somewhat by the winding capacity. It may be noticed that of the transformers whose characteristics are shown in Fig. 9, transformer B introduces minimum loss.

In designing a transformer to connect a resistance to a positive reactance, the impedance ratio of the transformer is determined as the ratio of the circuit

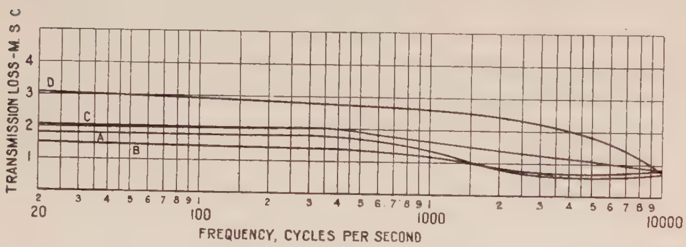

Fig. 9—Transformers Operating between a Resistance and a Positive Reactance

Transmission loss above that of an ideal transformer of the same ratio.
Sending end impedance $Z_1 = 6000$ ohms.
Receiving end impedance $Z_2 = (R + j L)\,\omega$ ohms $= 20 + j\,2000$ ohms at 1000 cycles.
Transformer impedance ratio = 3:1

Transformer	$\dfrac{M\sqrt{R}}{Z_1}$ at 1000 cycles
A	5
B	10
C	20
D	40

impedances at the frequency at which it is desired to deliver maximum power. The choice of best mutual impedance may be made by assuming windings of different impedance and predetermining their loss characteristics as has been described under transformers working between resistances.

Transformer Operating Between A Resistance and A Negative Reactance

Where a transformer operates between a resistance and a negative reactance, a condition exists where one impedance is independent of and the other is a function of the frequency, although in this case the reactance varies inversely with the frequency. Here again in order to deliver power it is necessary to assume that the receiving end impedance has a small resistance component. The transformer ratio may be made to match these impedances at any frequency, delivering maximum energy, but causing an increasing loss above and below this frequency. The loss characteristic of such a transformer is shown in Fig. 10 which gives the increase in transmission loss of the ideal transformer of fixed ratio over the ideal transformer of the actual ratio of the circuit impedances at all frequencies.

Referring to Fig. 5 and considering Z_2 a negative reactance, there are two frequencies at which resonance takes place. At the first frequency parallel resonance occurs between the impedance $M\sqrt{R}$ and $Z_2 R$ and at the second, series resonance occurs between the leakage reactance components of $P - M\sqrt{R}$ and $S R - M\sqrt{R}$ and the receiving circuit impedance $Z_2 R$. The d-c. resistance causes a loss which, in general, is finite at zero frequency and becomes zero at infinite frequency. The leakage reactance produces a loss which, in general, increases from zero at zero frequency to infinity at infinite frequency going through a minimum, however, and in some cases causing a gain over the ideal transformer at the second resonance frequency. The mutual impedance, in general, produces a loss which decreases from infinity at zero frequency to a finite value at infinite frequency going through a minimum, however, at the first resonance frequency and possibly even causing again over the ideal transformer at this frequency.

Input Transformer

The usual case of a transformer operating under these circuit conditions is the input transformer of the vacuum tube amplifier, the vacuum tube approximating a condenser in its grid-filament impedance.

With the receiving end impedance an ordinary capacity of constant phase angle, it is necessary in order to deliver uniform power over a range of frequency to match impedances at all frequencies or supply a voltage which decreases inversely as the square root of the frequency. In a vacuum tube amplifier, when the output or plate-filament current is proportional to the input or grid-filament voltage, uniform output

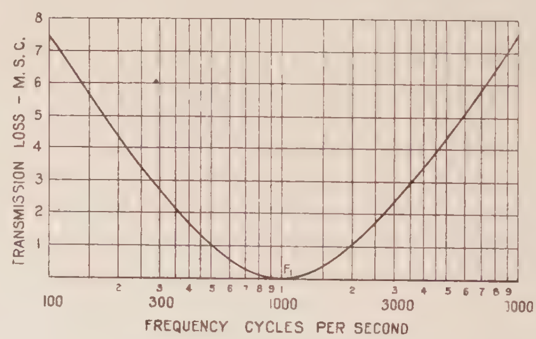

Fig. 10—Transformer Connecting a Resistance to a Negative Reactance

Ideal transformer of impedance ratio R/X at frequency "F_1" = 1000 cycles.

power will be delivered at varying frequency provided the input voltage is kept constant. When operating into a vacuum tube, therefore, it is not required to match the circuit impedances at all frequencies to limit distortion. An ideal input transformer of fixed ratio will tend to cause the vacuum tube to deliver uniform power over a range of frequency but only throughout that part of the frequency range in which it can maintain constant voltage across the grid-filament impedance.

The receiving end circuit impedance Z_2 is usually larger than Z_1. The equivalent unity ratio circuit and the equivalent T network of the equivalent unity ratio transformer are, therefore, obtained by dividing S and Z_2 by R and M by $\sqrt{R}$ instead of multiplying as in Fig. 5. Such an equivalent unity ratio circuit is shown in Fig. 11.

In considering the losses introduced in the circuit by the input transformer it is not convenient to compare the received current through the actual transformer with that of the ideal transformer of either variable or fixed ratio as neither ideal transformer delivers uniform input voltage to the vacuum tube at all frequencies or causes the amplifier to deliver uniform power. A more satisfactory basis of comparison, particularly for input transformers of different ratios which are intended for the same circuit conditions, is obtained by comparing the ratio of the potential produced across the grid-filament impedance Z_2 (see Fig. 3) to the potential E impressed on the circuit. This ratio gives the amount of effective amplification produced in the amplifier by the input transformer.

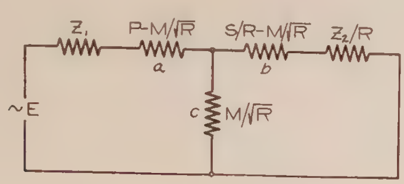

Fig. 11

The losses of the input transformer have the same general frequency variations as the losses of the transformer operating into an ordinary negative reactance except that at the first resonance frequency the losses produced by the mutual impedance $M/\sqrt{R}$ of the input transformer may be zero but never negative. It is to be noted that the d-c. resistance of the secondary produces zero loss at zero frequency while the loss due to the d-c. resistance of the primary is finite.

Input transformers designed for audio frequencies operate into the high negative reactance of the vacuum tube and therefore the secondary and mutual impedances are necessarily of large magnitude. The capacity of the transformer windings under these conditions becomes of considerable importance and even when limited by careful design usually causes parallel resonance in the arm c of the transformer network in the transmitted frequency range. The same is the case with input transformers designed for carrier frequency operation although the impedances involved are usually not so large. Above this resonant frequency both the arm c and the impedance Z_2/R are negative reactances and their impedances tend to be annulled by the leakage reactance of the arms a and b. The combined effect of the leakage reactances of these arms produces resonance with the transformer and tube capacities which may increase the transformer amplification characteristic even above the value given by the ratio of secondary to primary turns.

Amplification characteristics produced by transformers of different ratio operating from a sending end impedance of 20,000 ohms into a 216-A vacuum tube are shown in Fig. 12. It will be noted that as the impedance ratio of the transformer is lowered, the amplification characteristic flattens out and the frequency distortion is reduced. In the characteristics of some of the lower ratio transformers, a gain in amplification above the ratio of turns of the transformer may be noted at the higher frequencies.

It is to be noted that in the circuit of Fig. 11, a and b are positive reactances while at the high frequencies c and Z_2/R are negative reactances and the circuit approximates a low pass filter. As a filter, it has a cut-off frequency above which it tends to limit transmission and the amplification characteristic falls off quite rapidly.

The d-c. resistance of the primary is of more importance than the d-c. resistance of the secondary. In the well-proportioned input transformer, the value of the arm c particularly at the resonance frequency becomes very large as compared with the sum of the impedance Z_1 and the impedance of the arm a and at these frequencies the transformer gives practically the amplification represented by the ratio of secondary to primary turns. However, at the lower frequency range, where the impedance of the arm c becomes more nearly equal to the sum of the impedances of Z_1 and the arm a, the d-c. resistance of the primary produces a loss in amplification. The d-c. resistance of the primary is, therefore, a factor in the distortion at the lower frequencies.

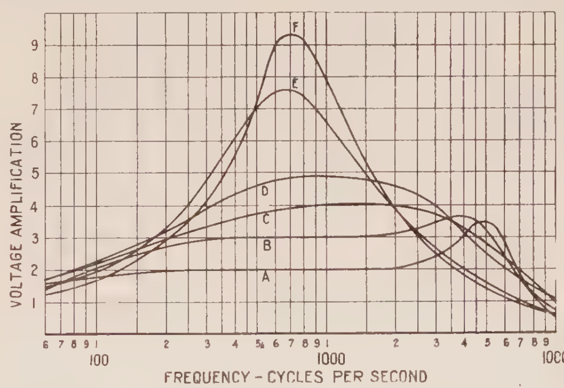

Fig. 12—Voltage Amplification Characteristics of Input Transformers of Various Turns Ratios Operating from 20,000 Ohms Resistance into a 216-A Vacuum Tube

Coils	Turns Ratio
A	1:2
B	1:3
C	1:4
D	1:5
E	1:8
F	1:10

For the rapid analysis of an input transformer, it is

customary to consider the d-c. resistance of P as added directly to Z_1 to form Z_0; to consider the total leakage reactance, $+ j X_1$, located entirely in the arm a; to neglect the d-c. resistance of S; to combine the capacity of the vacuum tube and effective capacity of the transformer as determined as located across S to form the reactance $- j X_c$ and to consider the mutual impedance M as the impedance due to the transformer windings exclusive of capacity. Such a circuit as shown in Fig. 13, approximates the actual circuit conditions quite closely in the ordinary case and is useful in design work.

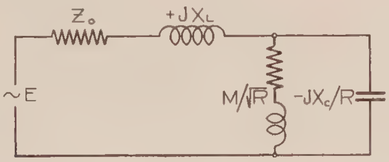

Fig. 13

For an audio-frequency input transformer of a given ratio, the losses or the departure from full amplification depend at low frequencies, principally on the value of the mutual impedance, while at high frequencies the effective capacity of the tube plus that of the transformer has a considerable influence. As the mutual impedance is a function of the number of turns, while the capacity is practically independent of the number of turns, it follows that, in general, for an input transformer operating over a wide band of frequencies, the higher the mutual impedance, the wider will be the transmitted frequency band.

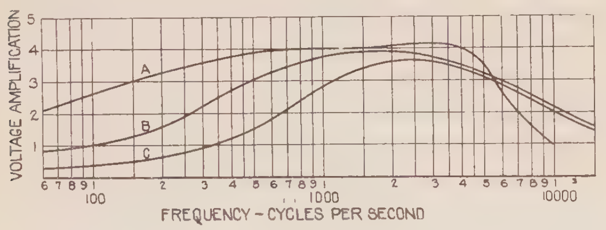

Fig. 14—Voltage Amplification of Input Transformers of Different Mutual Impedances

Impedance ratio of 1:16 and operating from 15,000 ohms resistance into a 216-A vacuum tube.

Transformer	Ratio $\frac{M \sqrt{R}}{15{,}000}$ at 1000 cycles
A	1:1
B	1:4
C	1:10

Fig. 14 shows the variation in amplification obtained with input transformers of the same ratio but of different mutual impedances operating between a resistance of 15,000 ohms and a 216-A vacuum tube. It will be noted that as the mutual impedance is increased the width of the transmitted frequency band is increased and the mid-band frequency is lowered. The upper slope of the frequency characteristic is determined principally by the leakage reactance of the transformer and the transformer and vacuum tube capacities. In transformer C the leakage reactance is so proportioned that resonance with this capacity extends the flat portion of the amplification characteristic upward in the frequency range. The lower slope of the characteristic is determined principally by the mutual impedance of the transformer.

This advantage of high mutual impedance explains the use of No. 40 and No. 44 A. w. g. enameled wire for the secondaries in most audio frequency input transformers, as giving the highest impedance secondary windings that can be commercially applied with different methods of winding. With the gage of wire and the secondary impedance thus determined, the possible amplification characteristic will depend on the transformer ratio. With a number of predetermined characteristics of different ratio transformers prepared as shown in Fig. 12, the required windings for the input transformer may be determined to give a desirable compromise between the amplification and the transmission distortion permissible.

From the standpoint of minimum distortion, it should be mentioned that it is desirable to use vacuum tubes of low plate-filament impedance in the amplifier, particularly if this can be done without sacrificing the tube amplification factor. The effect on the input transformer characteristic of operating it from tubes of different plate circuit impedance is shown in Fig. 15.

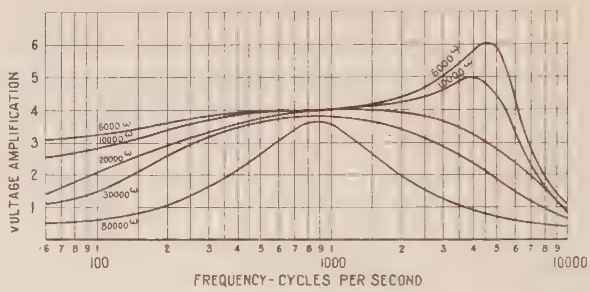

Fig. 15—Voltage Amplification Characteristics of an Input Transformer of Impedance Ratio 1:16 Operating from Various Resistances into a 216-A Vacuum Tube

In the earlier telephone repeaters,[6] a resistance was shunted across the secondary of the input transformer and the grid-filament impedance of the vacuum tube. This resistance was of sufficiently low magnitude to determine the impedance into which the input transformer operated and the transformer was given the proper impedance ratio to match this impedance with the impedance from which the transformer was operated. This resistance served to aid in obtaining a flat amplification characteristic and to fix the impedance measured on the primary of the transformer with the secondary connected in circuit. An impedance characteristic was produced as shown in Fig. 4 instead of the characteristic of the type shown in Fig. 2, which

6. Gherardi and Jewett: "Telephone Repeaters," Trans. A. I. E. E., Vol. 38, part 2, page 1287.

represents simply a transformer with appreciable effective capacity in the windings. Later on an improvement was made by shunting the primary of the input transformer with a resistance of a value equal to the resistance formerly used across the secondary divided by the transformer impedance ratio. It will be noted that in the first case, the transformer operates into a circuit which is principally a resistance while in the second case, it operates into a capacity.

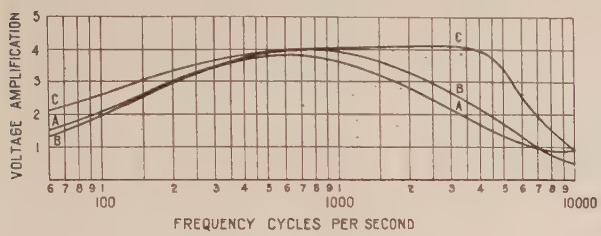

Fig. 16—Voltage Amplification of Input Transformers Under Different Circuit Conditions

Curve	Transformer Impedance Ratio	Resistance Across Low Side	Resistance Across High Side
A	1:64	∞	64 × 15,000
B	1:64	15,000	∞
C	1:16	∞	∞

Measured amplification characteristics of an input transformer operating under both circuit conditions are shown in Fig. 16 which gives, in addition, the characteristic of an input transformer of the same size and construction designed to give the same value of amplification as in the first two cases but without the shunting resistance. The superiority of the latter type of circuit in giving a uniform amplification characteristic is easily seen. This last circuit connection does not have an input impedance characteristic which is practically independent of frequency and it is, therefore, more limited in its uses.

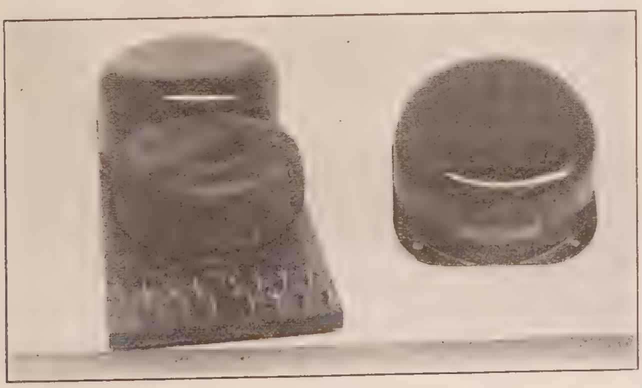

Fig. 17—Toroidal Repeating Coil

Transformer Construction

The type of transformer most used in the telephone plant is a toroidal core transformer usually called a repeating coil. This type of transformer has a ring-shaped core of soft magnetic iron wire or silicon steel laminations completely covered with the primary winding over which is applied the secondary winding. Such a transformer, when the dimensions are properly proportioned and the winding is applied so as practically to fill the central hole in the core, is a very efficient structure. The symmetrical distribution of winding limits the stray field, thus preventing cross-talk trouble in neighboring circuits. The cost of winding has been reduced to a low value by the development of a winding machine in which a circular shuttle threading through the center of the core is used to hold the wire which is wound on the core by a motor-driven annular part of the machine. The windings are accessible and permit of easy adjustment. This type of transformer is used in telephone installations where the impedances of the circuits in which the transformer is operated are less than 20,000 ohms and where the frequency is relatively low. The usual type of mounting of two repeating coils on a common base is shown in Fig. 17. The case has been removed from the front coil unit to show the construction.

The telephone induction coil used in all subscribers sets is an open magnetic circuit core type transformer.

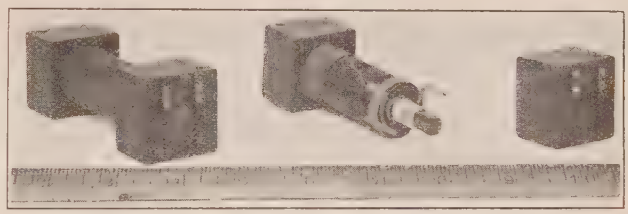

Fig. 18—Telephone Induction Coil

The impedance and frequency requirements of the circuit in which this form of transformer is used are not severe and the value of the transmission is relatively low due to the fact that any one transformer is used a relatively small part of the time and only for conversations from a single station. This, together with the facts that the transformer must be designed to operate with direct current through the windings and stray magnetic field is of no particular disadvantage permits the use of this relatively inefficient type of transformer shown in Fig. 18. It is to be noted that in this transformer the winding is located about the center portion of the core only as in this location the highest ratio of inductance to d-c. resistance is obtained giving maximum efficiency.

For portable test sets, considerably lighter and smaller types of transformer than are generally used in the telephone plant are required. Transformer *A* of Fig. 19 shows the type of transformer used in sets such as the S. C. R. 72 amplifier developed for the Signal Corps of the United States Army. This amplifier set was intended to operate on 1000-cycle telegraph signals

transmitted through the ground. The transformers used in this set were required to operate efficiently only in the neighborhood of 1000 cycles and transmission at other frequencies was sacrificed to obtain maximum amplification at this frequency. An amplification characteristic of the input transformer of this set is given in Fig. 20. This type of transformer was widely used in both Signal Corps and Navy radio transmitting and receiving sets throughout the war and weighed about two pounds.

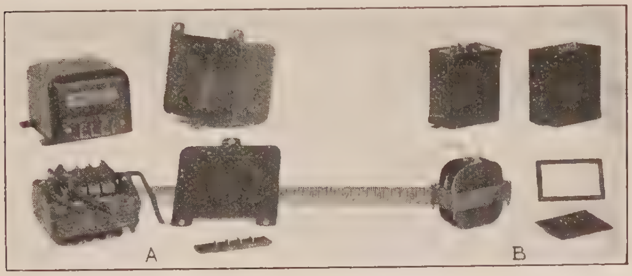

Fig. 19—Shell Type Transformers.

The type of transformer shown as B in Fig. 19 is also of shell type construction and is used in portable telephone field test sets and weighs 12 ounces.

One of the latest designs of shell type transformer and the one which was used for most of the experimental characteristics given herein is shown in Fig. 21. The construction of this input transformer, the No. 224 type, is such that winding and assembly can be readily

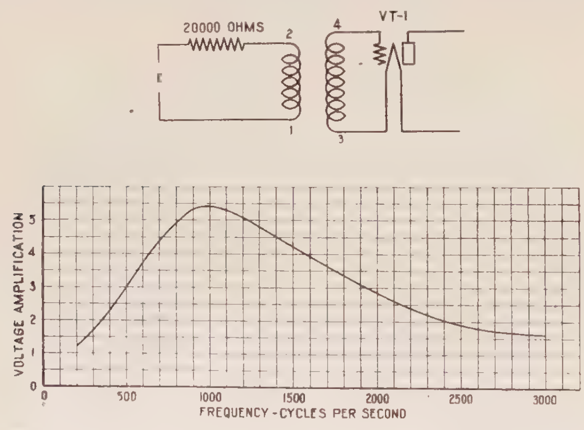

Fig. 20—Amplification Characteristic, 201-A Input Transformer

accomplished and repair easily effected if necessary. The winding space and the core have been proportioned to obtain minimum cost of manufacture. The core consists of I and E shape laminations riveted together to form an I and E part which butt together forming the core. The winding is placed on a spool which fits over the central limb of the E. The two core parts are held together by means of two brackets which are held in place by four machine screws. The terminals are arranged on insulated mounting plates held under the screws of the mounting bracket and serving as mechanical protection to the lead wires.

It may be noted that whereas the form of toroidal repeating coils is core type, that of the transformers employing spool windings is shell type. The core type is used for the toroidal repeating coils as it permits ready adjustment of the windings and the shell type is used in the transformer having spool windings as it permits the use of a winding of small effective capacity.

The size of the transformer is governed by three factors, the amount of space available, the cost permissible and the ratio of inductance to d-c. resistance which is required to give the desired freedom from transmission loss.

In the windings of telephone transformers, cotton or cotton and enamel is used for the insulation of the heavier gages of wire while for the smaller gages, enamel or enamel and silk is used. The gage sizes used range from No. 18 A. w. g. or heavier to No. 44. In input transformers, the d-c. resistance of the secondary winding usually causes an inappreciable loss and it

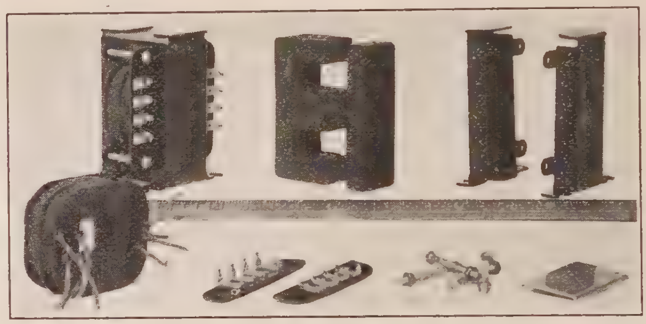

Fig. 21—224-Type Input Transformer

is, therefore, desirable to have it take up as little space as possible and the smallest size of wire which can be used with the different commercial methods of winding is employed. The quality of the enamel insulation generally used for this winding is a determining factor in the minimum size of winding which can be used. With the best enamel, it is possible to wind No. 40 A. w. g. wire with little or no interleaving paper and with little special machinery, and have the resulting windings reasonably free from short circuits. However, with inferior enamel, it is necessary to use a covering of silk in addition to the enamel, or to use interleaving paper between each two layers of the winding. This extra insulation, needless to say, causes a considerable increase in the space taken up by the winding, which is undesirable.

In transformers in which the effective capacity is an important factor, it is frequently necessary to apply the winding in such a way as to reduce the capacity to a minimum. The effective capacity depends on the size of the transformer winding, more care being

required to reduce it to a reasonable value in a large than in a small transformer. The capacity of the winding may be conveniently considered as composed of four parts, part one being the sum of the capacities between each two adjacent turns all connected in series from one terminal of the winding to the other, part two the sum of the capacities between adjacent layers in series, part three the capacities between adjacent winding sections in series and part four due to the capacities between the winding and any other metal or other windings in the neighborhood. These capacities may be considered in effective values as connected across the winding terminals. Of these component capacities, the first may usually be neglected entirely, as it consists of a large number of small capacities in series, this number being only slightly less than the

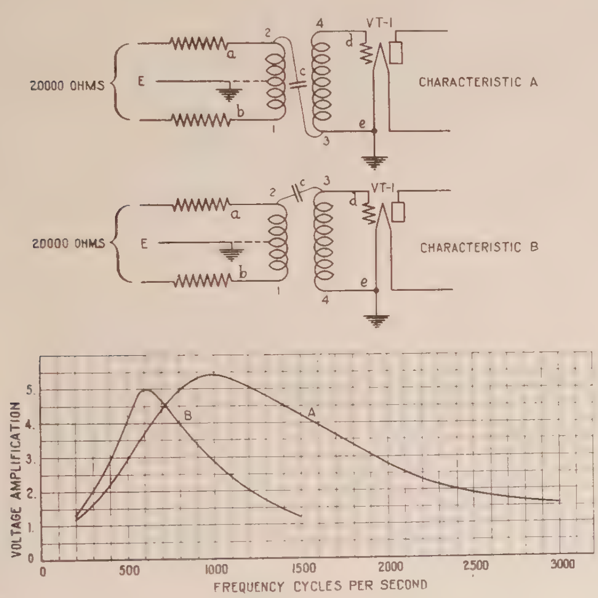

Fig. 22—Transformer Amplification Characteristics with Different Winding Connections

total number of turns. The fourth part is usually the most important as it seldom consists of more than two capacities in series. The second and third parts of the effective capacity are of importance depending on the number of sections and layers and the capacity between adjacent ones. In high ratio transformers, it is usually sufficiently accurate to consider the lower impedance winding as an equi-potential plate and to consider the capacities with regard to the high impedance winding only.

The effect of inter-winding capacities in affecting transmission is given in Fig. 22. This figure shows how sometimes these capacities may be connected between approximately equal potential points in the circuit and thus lessen the effective capacity of the winding. The transformer on which these characteristics were taken is the same as that shown in Figs. 19 and 20. Characteristic A represents the normal connection of windings with the interwinding capacity C located between the parts of the circuit a and e in which it is effectively across one half the impedance of the primary, 1-2. Characteristic B shows the amplification obtained with the secondary winding, 3-4, reversed, terminal 3 being connected to the grid of the vacuum tube instead of the filament. In this case the capacity C is across the entire secondary impedance in addition to one-half the primary impedance, the combined impedance being approximately 200 times the impedance under the circuit connection A. The effect of this inter-winding capacity being connected across points of widely different potential in the circuit in lowering the frequency of the amplification peak is clearly shown.

Transformers are subjected in service to conditions of temperature and humidity which vary greatly. Conditions in exchanges in the tropics and in certain sets for outdoor use are particularly severe while in some other locations there is but little chance of trouble. Under conditions of humidity electrolytic corrosion will take place provided salts which might form an electrolyte on the addition of moisture are present in the completed windings. Corrosion will be accelerated in circuits in which there is a direct-current potential between some point in the winding and another neighboring metallic part. It frequently causes the windings of the transformer to open-circuit particularly when they are wound with the smaller gages of wire. It is rather difficult to obtain materials which are free from slight amounts of salts and to keep the transformer winding free from them during the operations incident to manufacture. Perspiration from the operators hands or the use of soldering salts are common causes of corrosion. To reduce this trouble the windings are imbedded in a moisture resisting compound of oils or waxes which is in itself chemically inert. The moisture-proofing process is usually effected under vacuum after a baking period. The advantages of a carefully worked out moisture-proofing treatment in prolonging the useful life of transformers is so great that it has been universally adopted in all carefully designed transformers.

In the foregoing, the transformer has been treated from the standpoint of the transmission of telephone currents and those features have been presented which appeared to the writer to be of special interest and usefulness to those interested in its application to this problem. In conclusion, the writer wishes to acknowledge his indebtedness to Mr. Thomas Shaw of the American Telephone and Telegraph Company and to Mr. K. S. Johnson of the Western Electric Company, Inc., with whom he has been associated for a number of years on the general problem of telephone transmission and in the application of the principles described herein.

Radio Telephone Signaling

Low-Frequency System

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***Review of the Subject.**—A signaling system is described which serves to extend to the field of radio telephony the same sort of calling facilities as are now available in wire telephony. By its means the radio attendants or subscribers are enabled to signal each other without requiring that the called party should have to listen with a receiver. The system is intercommunicating with a capacity for a large number of stations on one wave length. It has a range of operation extending as far as a radio channel suitable for the commercial transmission of speech can be reliably maintained, and offers a very satisfactory degree of freedom from interference. Furthermore, it employs simple, standard types of telephone apparatus. Some possible fields of usefulness of the system, its outstanding characteristics, and the apparatus which it employs are described.*

Introduction

In any system of communication, it is desirable that means be provided whereby an attendant or subscriber may be called without requiring that he should have to listen on a particular line. In wire telephone systems, as is well known, means are provided whereby the central office operator may ring a subscriber's bell. In addition, signaling equipment is provided which permits calling the attention of the central office operator at either station on a line to a particular circuit, without requiring her to listen on that circuit. Thus, it is possible for the operator, after she has established the desired connections between certain circuits, to give her attention to others.

The need of such independent signaling facilities for radio systems has not in the past been an important factor, on account of the fact that licensed operators have been required by law to stand watch at all transmitting stations. However, in certain of the various commercial applications of radio telephony which are now being considered, it is undoubtedly true that the licensed operators on continuous watch could be dispensed with, without detriment to the public safety and, in these instances, signaling facilities would be a distinct advantage.

To anticipate these needs, the development of signaling arrangements suited to practical use with radio systems has been undertaken and much progress has been made. The problem involves the difficulty that the communication channel provided by radio may be less easily maintained in a stable condition than a wire channel. However, it is now felt that it will be practicable to provide signaling facilities adapted to any type of radio telephone service for which a channel suitable for the commercial transmission of speech can be reliably maintained. This will be of considerable advantage, it is thought, in the commercial development of such service.

One promising possibility for the use of this signaling system would seem to be in the field of marine radio telephony. In ship-to-shore radio telephony automatic signaling would serve to lessen the radio operators' duties. Undoubtedly, there would be considerable operating advantage, from a commercial standpoint, in placing the ship-to-shore radio telephone service on the same signaling basis as wire lines. This might be expected to become particularly important if the volume of such radio telephone traffic became large.

Among other commercial applications of radio telephony in which signaling facilities are expected to prove advantageous, might be mentioned the point-to-point service. A radio telephone system for such a service is being installed by certain interests in Persia as a means of communication between points not reached by wire systems. An automatic signaling system of the type described in this paper is to be employed in this case, and a number of intercommunicating stations are expected to be involved eventually. In the United States there has not, thus far, been much field for the commercial application of point-to-point radio telephone systems. However, where conditions do not favor the installation of wire lines, as in the Persian case, point-to-point radio systems may be expected to find application.

Description of Basic System

The experimental work has indicated that a low-frequency signaling system employing a mechanically tuned alternating-current receiving relay is well adapted to operation in connection with radio systems. Such an arrangement has been shown to be both highly selective and sensitive. These qualities result in giving a very satisfactory degree of freedom from interference, while at the same time the signaling energy level required is so low as to permit operation directly from a radio set employing the smallest available types of vacuum tubes.

With such a system, standard types of apparatus may be employed for the signaling equipment, which is not expensive as compared with the cost of the remainder of the radio equipment. Furthermore, the ordinary

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types of radio transmitting and receiving circuits may be used, without modification.

In testing the system over short distances a simple radio transmitter was used, employing one modulating and one oscillating tube, each of the so-called *E* type. This transmitter had an output capacity of about 5 watts at wave lengths between 200 and 450 meters.

Any type of radio receiver which is suitable for receiving speech over the particular radio system employed may be used. In the tests, one having two stages of radio-frequency amplification, a detector and one stage of audio-frequency amplification, all of which utilized the small *N* type vacuum tubes, was employed. The signal-receiving apparatus was operated either from the detector tube or the audio-frequency amplifier, depending upon the signaling range desired.

Fig. 1 shows this scheme in its most simple form which may be made to serve as the basis for a variety of systems, suited to different purposes. As seen in this figure, the outgoing signal is produced by applying an alternating current of a particular frequency to the radio transmitter in the same manner as the speech currents are applied. Modulation of the radio carrier wave at the signaling frequency results. In this particular system, the signaling current frequency employed is 135 cycles.

At the receiving end the radio carrier wave, modulated by the signaling current, is detected in the radio receiver in the usual manner. The output of the detector thus includes a component similar to the signaling current originally sent into the radio transmitter at the outgoing end.

This received signaling current is sent into an alternating-current relay of a type particularly adapted to the purpose, which serves to close a sensitive direct-current relay in a local circuit. This combination of relays acts as a mechanical rectifier.

Fig. 2 represents very roughly the form of the signaling currents at the various stages in the process of operation of the basic system. In this figure, the operation at the transmitting end is shown at *A*, *B* and *C*, while that at the receiving end is shown at *D*, *E*, *F*, and *G*. Such a graphical representation of these currents cannot, of course, be made accurate in a quantitative sense, but it permits visualizing the character of the signal at different steps in the process of operation.

At *A* in this figure is shown the direct-current impulse through the sending key and direct-current signal-transmitting relay, which occurs when the key is closed.

The operation of the signal transmitting relay, which occurs when the sending key is closed, supplies 135-cycle current to the radio transmitter as shown at *B*.

The modulation of the radio carrier wave by the 135-cycle current results in antenna current of the form shown at *C*. This consists of the radio frequency current varying in amplitude at a rate dependent upon the frequency of the impressed signaling current.

The form of the incoming current in the antenna or loop at the radio receiving station, as shown at *D*, is the same as that of the transmitted antenna current previously shown at *C*, but is of course greatly attenuated.

This radio-frequency current, varying in amplitude at a rate dependent upon the modulating frequency of 135-cycles, is impressed upon the detector in the radio receiver. The detector functions in the usual manner, giving as one of the components of its output, 135-cycle current as shown at *E*. This is similar in form to the signaling current originally sent into the transmitter, as shown at *B*.

The 135-cycle component of the detector output is sent into the alternating-current relay and causes its mechanically tuned reed to vibrate at a corresponding rate. The vibration of the reed closes the local circuit through its contacts and the sensitive direct-current relay intermittently. This results in a uni-directional pulsating current through the sensitive direct-current relay, as shown at *F*, and holds the latter closed.

The sensitive direct-current relay, thus operated through the contacts of the vibrating reed, serves to close the circuit through a secondary relay suited to operate directly the local signal. The form of the

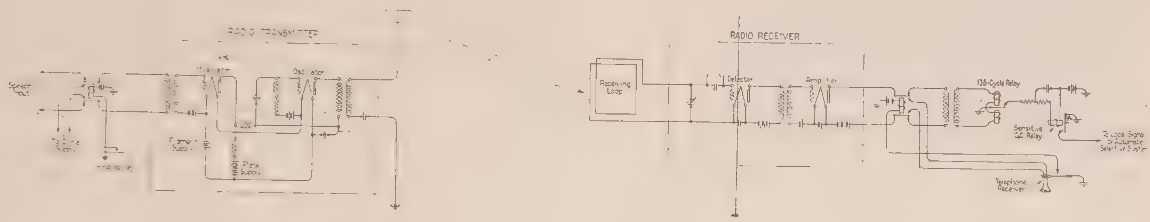

Fig. 1—Simplified Diagram of Basic System for 135-Cycle Signaling

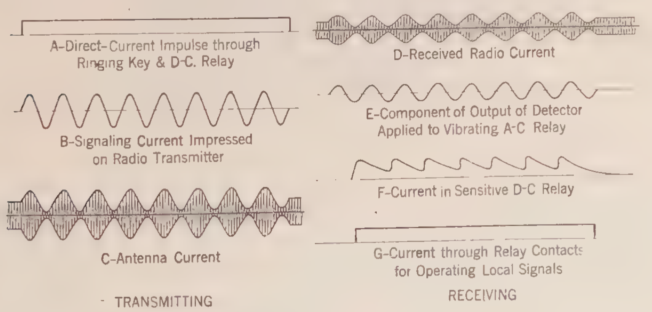

Fig. 2—Form of Transmitted and Received Signaling Currents in Operation of Basic System

current at this point, as shown at G, corresponds closely to the original signal-transmitting impulse through the sending key and direct-current relay, as shown at A. The operation of the secondary direct-current relay in this manner constitutes the conclusion of the final step in the functioning of the basic signaling system. Subsequent steps depend upon the type of signaling facilities desired, as will be described later.

Operation of Alternating-Current Relay

The reliability and range of operation of this system are due in a large measure to the characteristics of the particular type of alternating-current relay used.

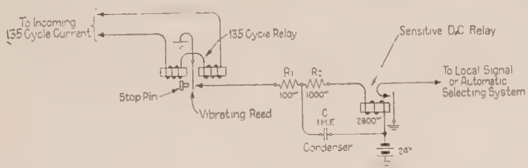

Fig. 3—Secondary Circuit of 135-Cycle Relay

This relay is unusually sensitive, as it will operate on as little power as 30 microwatts corresponding to a current of about 0.25 milliampere. The selectivity of the relay is such that a 4 per cent change in the frequency of the signaling current necessitates doubling the current to give equally effective operation of the relay.

Fig. 3 shows the arrangement employed in associating the vibrating reed relay with the local circuit. It is seen from this diagram that the vibrating reed intermittently closes a circuit associated with a sensitive direct-current relay in such a way that the latter is held closed. The direct-current relay is held operated without vibration, as long as the reed of the a-c. relay is vibrating at the frequency of the signaling current.

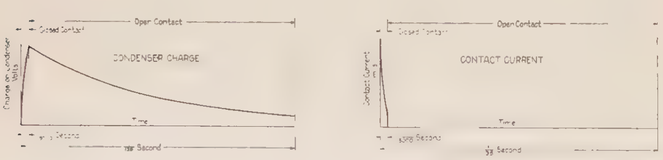

Fig. 4—Characteristic Curves Showing Operation of Secondary Circuit of 135-Cycle Relay

The action of this particular local circuit is such that effective operation of the a-c. relay may be obtained with a very small 135-cycle current. The condenser connected in parallel with the sensitive direct-current relay and the resistance in series with the condenser are so chosen in value that the condenser will take an effective charge from the local battery in a short period of time. Thus, but a small amount of work is required to be done in the form of contact pressure by the vibrating reed to charge the condenser to the degree necessary to operate the sensitive direct-current relay by discharging through the winding of the latter.

The curves shown in Fig. 4 indicate approximately the relation between the condenser voltage and contact current over a period of time corresponding to one cycle, that is 1/135 of a second. From these curves it is seen that the contacts need be closed for only a small fraction of the cycle. Thus, little energy need be expended to effect the operation of the local relay.

Fig. 5 is a typical curve showing the performance of the relay in relation to the frequency of the signaling current under average conditions of adjustment. The mechanical tuning of the reed is largely responsible for

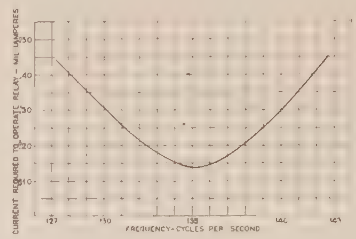

Fig. 5—Typical Curve Showing Frequency Characteristics of 135-Cycle Relay Under Average Conditions of Adjustment

its selectivity. The reed is adjusted so that the natural period corresponds closely to the frequency of the signaling current. It is thus very selective and is relatively free from the ordinary sources of electrical interference such as those caused by telegraph signals, static, voice currents, etc.

Fig. 6 shows the general structure of the relay. The relay is provided with plug connections so that it may be inserted in the circuit or removed from it readily, without requiring soldering of connections. Thus, it is convenient to make necessary ajustments of the

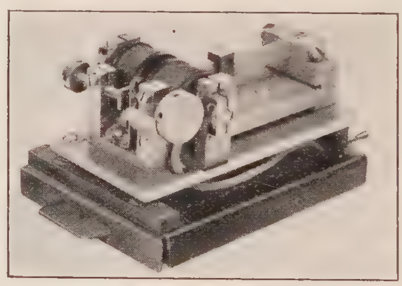

Fig. 6—Structure of 135-Cycle Relay

relay separate from the circuit with which it may be associated in service. The relay is well protected from interference due to mechanical vibration by padding in the mounting. This eliminates rigid mechanical connection between the relay and its external support, thereby preventing loss of energy. A stop-pin is also provided which prevents undue vibration of the reed due to transient impulses or excessive currents.

Signaling Current Frequency

The signaling current frequency used in the practical application of this system, as previously mentioned, has

been 135 cycles. This has had the advantage of being a frequency which is low enough to be relatively free from the various kinds of interference experienced in radio systems and at the same time permit the use of simple and reliable apparatus. The fundamental features of the system, however, are such as to permit its being adapted to use with other low frequencies, if such should be desired.

The inherent advantages in the use of a frequency well below the ordinary voice range for telephone signaling, may be readily made effective in a radio telephone system, since there is ordinarily nothing in such a system to discriminate against the lower frequencies. In fact, as far as the radio characteristics of the system are concerned, what difference there may be is in favor of the lower frequencies, because of the close approach of the modulated carrier wave in this case to the carrier frequency itself. While this factor may not be practically important with the short-wave systems now commonly used in radio telephony, it is more likely to be of account with longer waves.

The high degree of freedom from interference which is obtained with this system is in a measure due to the use of a frequency as low as 135 cycles for signaling. This is particularly true with respect to the interference caused by spark and I. C. W. telegraph. The tones from these sources, being within the audible range, are likely to interfere with any system tuned to a normal voice frequency. 135 cycles, however, being well below these frequencies, permits the effective use of both electrical and mechanical tuning in the signal-receiving apparatus to discriminate against interfering currents. This point was well demonstrated in the signaling tests in which it was found that radio telegraph signals similar to those from an I. C. W. or spark transmitter would cause the received speech to become unintelligible when the energy level of the interference was only 20 or 30 per cent of that required to cause the signaling system to fail.

Another advantage in low-frequency signaling occurs when the signaling apparatus is desired to be bridged across the talking circuit. In this case greater efficiency results in the use of 135-cycle signaling, by reason of the fact that it is possible with this low frequency to pass a large proportion of the received signaling energy into the signaling circuit. If a much higher signaling frequency were used, such that it occupied a more important part of the speech range, an undesirable loss might be caused by an efficient signaling circuit.

135-Cycle Supply

The highly selective signal-receiving apparatus which is used in this system permits a greater sensitivity in reception when the outgoing signaling currents are kept closely to the desired frequency. This has been accomplished practically by the development of a 135-cycle interrupter capable of maintaining close regulation and an output of good wave form.

Fig. 7 shows the circuit arrangement of the interrupter which has been developed for commercial use. This employs a tuned vibrating reed actuated by an electromagnet when direct current is applied. The contacts on the reed being in series with the battery circuit, vibration of the reed is effected in the manner of an ordinary buzzer. The actuating circuit of the

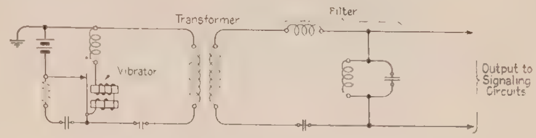

Fig. 7—135-Cycle Interrupter Circuit—Simplified Diagram

vibrator is bridged by the primary side of a transformer in series with a condenser, the secondary side of the transformer being connected to a filter for suppressing harmonics in the output.

Fig. 8 shows the structure of the vibrator for the interrupter. Since the output frequency of the interrupter for a given applied voltage depends upon the

Fig. 8—Structure of Vibrator for interrupter

natural period of the reed, means are provided for closely adjusting the latter. It will be noted that this consists of a weight, the position of which along the reed is adjustable. This weight is used in making the initial adjustment of the vibrator to give 135 cycles at the normal battery voltage, but variations in adjustment are not required in subsequent operation of the interrupter.

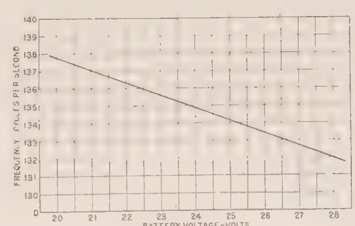

Fig. 9—Typical Curve Showing Relation between Frequency of Output and Applied Voltage for 135-Cycle Interrupter

This matter of frequency regulation is a most important one in the performance of the interrupter. As shown in Fig. 9, the frequency of the output may vary several cycles for a variation in the applied voltage of 20 to 28 volts. This voltage variation represents the maximum which might be expected to occur with an 11-cell storage battery operated on a charge and dis-

charge basis, without any regulating device. If the battery voltage is maintained within closer limits than 20 to 28 volts, as may be accomplished by various means, it is seen from the curve in Fig. 9 that correspondingly closer regulation of the output frequency may be obtained. For example, if duplicate batteries of adequate capacity are available, the applied voltage may be kept within limits such that the output frequency will vary only about one cycle.

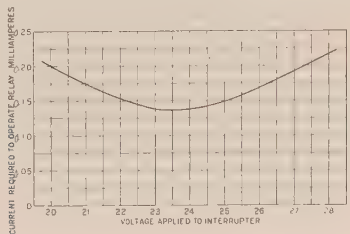

Fig. 10—Typical Curve Showing Effect of Change in Frequency Due to Variation in Voltage Applied to 135-Cycle Interrupter on Current Required to Operate 135-Cycle Relay Under Average Conditions of Adjustment

average conditions, affect the current requirements of the receiving relay. By keeping the battery voltage within fairly close limits, reliable operation on smaller currents may be depended upon. Where desired, advantage may be taken of the closer frequency regulation obtained in this manner to secure greater signaling range.

The maximum output capacity of this interrupter is about three-fourths of a watt. The output voltage varies from about 25 volts at no-load, to 20 volts when the load is 35 milliamperes and 12 volts for a load of 60 milliamperes.

In certain of the signaling tests over short distances, a simplified form of the above interrupter was used. Under the testing conditions in this case, a smaller 135-cycle output was sufficient for the purpose and it was possible to reduce the size of the filter for the interrupter and to operate it with a 6-volt battery instead of a 24-volt battery.

Automatic Selective Signaling System

This signaling system may be adapted readily to automatic selective operation, whereby any one out of a

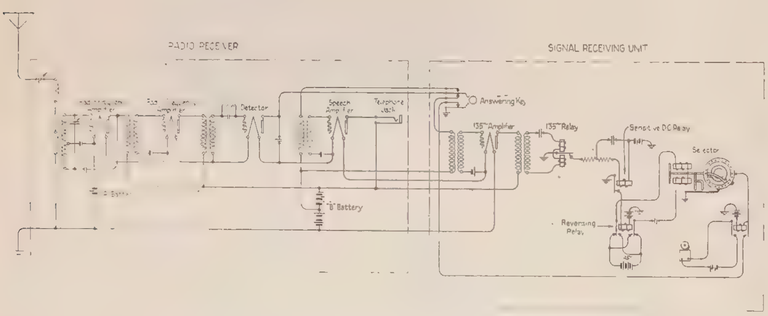

Fig. 12—135-Cycle Selective Signaling System—Circuit Arrangement of Receiving Aparaptus

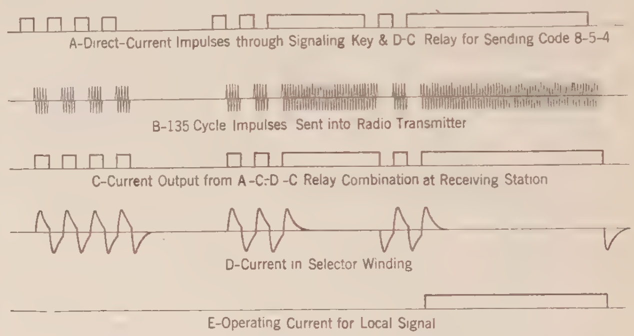

Fig. 13—Form of Transmitted and Received Currents in Operation of Selective Signaling System

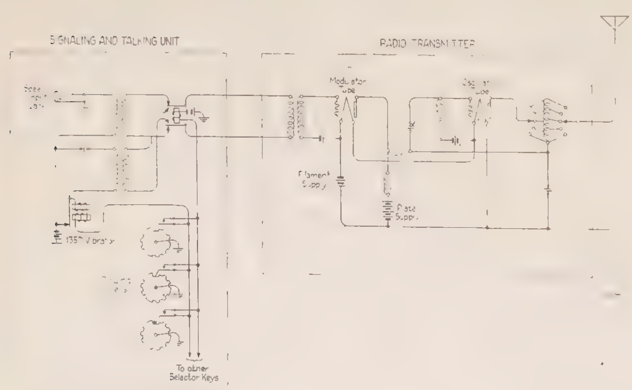

Fig. 11—135-Cycle Selective Signaling System—Circuit Arrangement of Transmitting Apparatus

Fig. 10 combines the voltage-frequency curve for the interrupter and the frequency-current characteristic of the relay to indicate directly how variations in the voltage applied to the interrupter and the consequent changes in output frequency may, under

number of stations on the same wave length may be signaled individually, or all may be signaled simultaneously. This form of the system is expected to be particularly useful in radio telephony, since a number of intercommunicating stations may often be involved as in the marine and point-to-point services. The illustrations which follow will give a picture of a typical arrangement of the automatic selective system.

From Fig. 11 the operation of the circuit at the transmitting end is seen to be as follows: The signaling key for the station which it is desired to call is operated and serves to produce a series of direct-current impulses in the form of a code corresponding to that assigned to the called station. For example, if a certain station is desired whose code signal is 8-5-4, a series of direct-current impulses suitable to indicate this number are sent out. These direct-current impulses operate at first a direct-current signal-transmitting relay which connects to the radio transmitter corresponding impulses of 135-cycle current, in such a manner as to modulate the outgoing carrier wave with current of this frequency

in a coded series of impulses each similar to the single impulse described in connection with the basic system.

As shown in Fig. 12, at the receiving end the radio receiver serves to detect the 135-cycle signals in the manner described in connection with the basic system, and these signals are sent into the alternating-current relay which operates in accordance with the code originally transmitted. This causes the sensitive direct-current relay to operate in accordance with the code and to produce in a local circuit direct-current impulses corresponding to the original impulses sent out at the transmitting end. These impulses then serve to operate a reversing relay which reverses the potential applied to a condenser in series with a stepping mechanism known as the selector, such that when the proper combination of impulses is received, the mechanism closes a circuit arranged to operate the desired local signal.

The functioning of the selective system may be followed in greater detail, by considering the form which the signal takes at various stages. Fig. 13 shows graphically the general form of the signaling currents in the successive steps necessary to transmit a typical code signal, such as 8-5-4.

The form of the original code signal, as applied by means of the sending key to the winding of the direct-current signal-transmitting relay, is shown at *A*. It is seen from this that the number of impulses sent is equal to each of the numbers in the code, either the making or breaking of the current (and consequently either the closing or opening of the signal-transmitting relay) counting as one impulse. This is due to the use of reversals in the final receiving operation, as will be explained later.

Each time the signal-transmitting relay is closed by the dirrect current applied through the sending key, 135-cycle current is supplied through the contacts of this

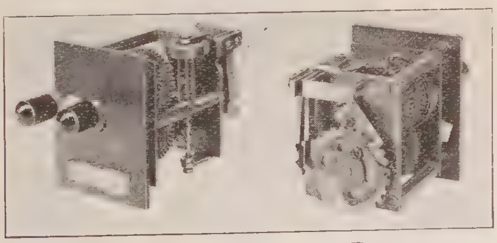

Fig. 14—Code Sending Key for Particular Station

relay to the radio transmitter, thus the signaling currents impressed on the radio transmitter for the code signal 8-5-4 are as shown at *B*.

These coded impulses of 135-cycle current serve to modulate the transmitted radio wave so that the antenna current is similar to that previously shown for the basic system, excepting that the 135-cycle modulation of the carrier is interrupted in accordance with the code.

The incoming current at the receiving station is similar in form to the transmitted antenna current. The component of the detector output which is useful in transmitting the signal consists in 135-cycle impulses which are similar in form to those sent into the radio transmitter, as previously shown at *B*.

The operation of the alternating-current relay, as previously explained, serves to operate the sensitive direct-current relay in accordance with the transmitted code. The contacts of this relay close and open the circuit through the reversing relay. The current in the winding of the reversing relay is as shown at *C*.

Fig. 15—Master Code Sending Key

The reversing relay reverses the potential applied to the condenser in series with the selector winding. The selector is arranged so that it operates on the charge and discharge of this condenser. The operation of this relay reverses the battery connections to the condenser and selector, causing the condenser to discharge and charge to the opposite polarity whenever the relay picks up or releases, and it is this charging current which operates the selector. These reversals take place in accordance with the original code and produce a current in the selector winding as shown at *D*. When the proper code is transmitted, the selector closes a local circuit causing direct current, as shown at *E*, to operate a signal. The final impulse of the series of impulses shown at *D* causes the selector to release and return to normal.

The apparatus employed in this typical arrangement of the system is of a type which has been used in connection with railway dispatching systems and is consequently available in a reliable commercial form. The selecting apparatus consists of the code sending key and the receiving selector mechanism.

Fig. 14 shows the structure of one type of sending key used for this purpose. This key is set to give the desired code for a particular station. Thus, at the sending end it is necessary to have a separate sending key for each station to be signaled.

Fig. 15 shows the structure of a master sending key. This is arranged so that it may be adjusted by the operator to send out any desired code in the system.

Thus, where this type of key is used but one is required at the sending end for signaling all stations.

Fig. 16 shows the structure of the receiving selector mechanism with the cover removed. This piece of apparatus consists essentially of a polar relay with a ratchet attachment so arranged that successive operations of the relay, at the proper speed, cause the stepping around of a contact wheel. Stop-pins are provided at certain points to prevent the contact wheel from returning to its normal position when the regular sequence of stepping is interrupted at these points. Any interruption of the regular sequence of stepping when the contact wheel is at any other point causes it to release. When the contact wheel has operated over 17 steps a contact is made which operates a signal. Thus, it is seen that to operate the selector so as to give a signal, the direct-current pulses must occur in the proper sequence and the pauses between the groups of pulses must occur at points where stop-pins are located.

The apparatus which has been described is arranged so that as many as 78 stations on one wave length may be signaled separately. The same apparatus can also be arranged so that at each one of the 78 stations, four separate supplementary stations can be individually signaled. For example, if a marine radio telephone system is involved, any one of four stations on each of 78 boats could be signaled separately. With a further slight modification in the apparatus, the same system is capable of being extended to permit the separate signaling of any one out of more than 200 stations. In each of these cases it is also possible to signal all of the stations simultaneously, when desired.

Fig. 17 shows how a system like that which has just been described may be arranged for two-way operation. This embodies a duplication at both ends of the features of the one-way system. With such an arrangement, any one station of a number operating on a given wave length may signal any other station in the same system, without calling in stations not desired. Such a system might be used, for example, between ships equipped with radio telephone systems or between the ships and the shore, where signaling any one of several shore stations might be desired. It might also be used for intercommunication between a number of fixed stations in a point-to-point system.

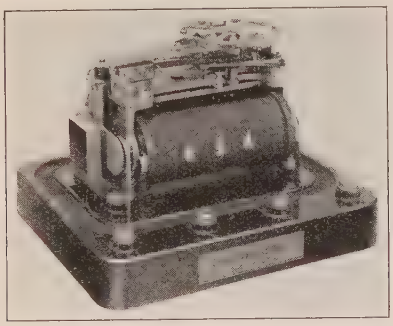

Fig. 16—Receiving Selector Mechanism

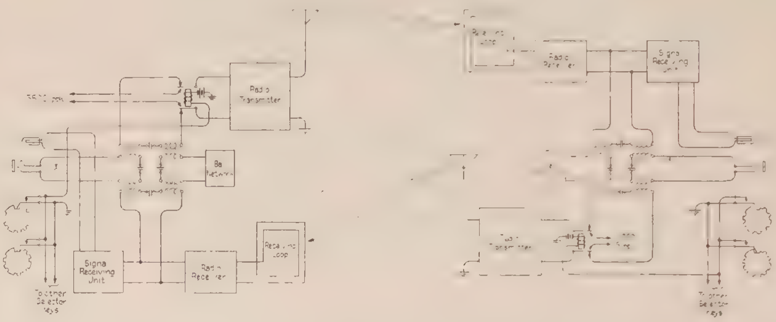

Fig. 17—Simplified Diagram of Two-Way Radio System Arranged for Automatic Selective Signaling

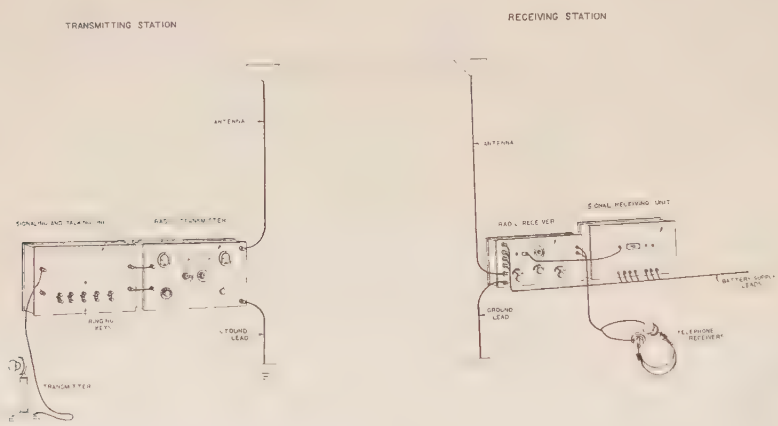

Fig. 18—135-Cycle Selective Signaling System—Typical Arrangement of Apparatus for One-Way Operation

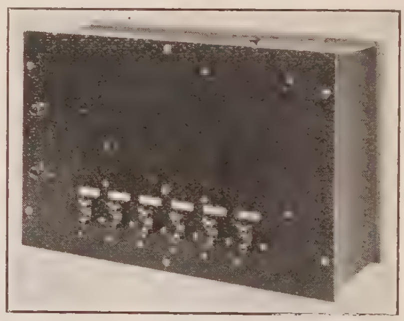

Fig. 19—Signaling and Talking Unit

Form and Assembly of Equipment

In the possible uses of this signaling system which have been mentioned as likely to have the most immediate commercial application, the signaling apparatus is a part of the radio attendant's equipment rather than the telephone subscriber's apparatus. The apparatus chosen for the purpose is, therefore, in a form which is well suited to central station use, although it has no features which would prevent its being used conveniently at a subscriber's station if the service required it.

In assembling the signaling equipment a uniform panel arrangement has been developed, with the idea that the various units might be used interchangeably in meeting the requirements of different types of installations. To this end, all apparatus has been mounted on panels

Fig. 20—Assembly of 135-Cycle Interrupter

of a uniform length of 19 inches. The height of the different panels has varied according to the amount of apparatus in each unit, but this vertical dimension has in each case been a whole multiple of the basic dimension of 1¾ inches.

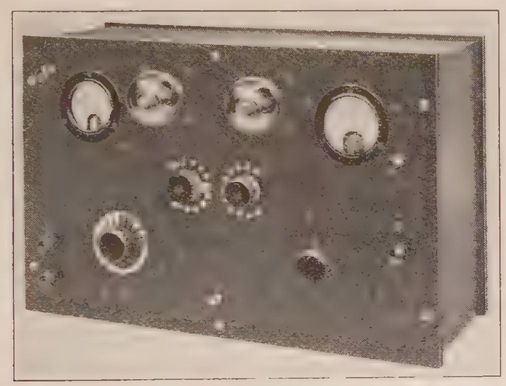

Fig. 21—Experimental Radio Transmitter Unit

By this means it is possible to mount the units in any desired manner. If, for example, it is desired to locate the radio and signaling apparatus on a desk or table, each equipment unit constitutes the front panel of a separate box. Fig. 18, shows the various units required

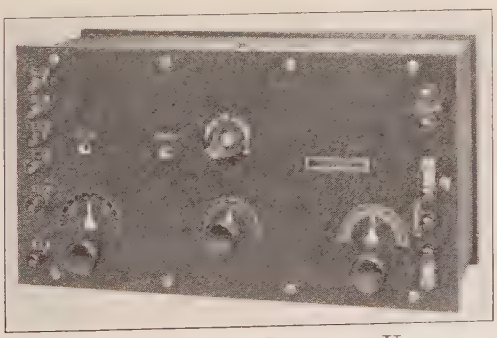

Fig. 22—Radio Receiver Unit

to make up a complete one-way system mounted in this manner.

Fig. 19 shows in more detail the signaling and talking unit of this group. This unit includes the sending keys, a simplified form of 135-cycle interrupter suited to use with the experimental set, and a six-volt dry cell battery for operating the interrupter and signal-transmitting relay. It also includes an induction coil and talking battery for use with a telephone transmitter.

Fig. 20 shows a separate 135-cycle interrupter unit which also employs the standard panel assembly. Removable covers are provided on both the front and back of the panel to protect the apparatus from

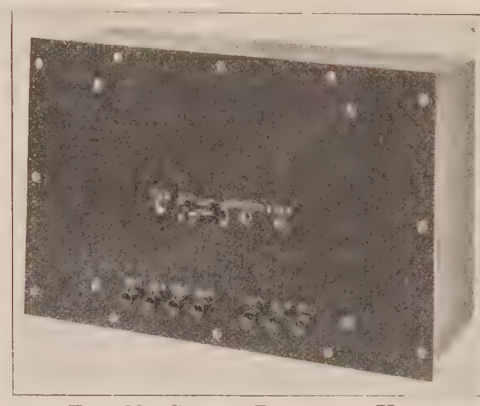

Fig. 23—Signal Receiving Unit

mechanical injury. This interrupter is of a type adapted to commercial use with radio transmitters of various forms and output capacities. It employs the circuit arrangement previously described in the section on "135-cycle Supply."

Fig. 21 shows an experimental radio transmitter unit of the type which was used in making certain of the

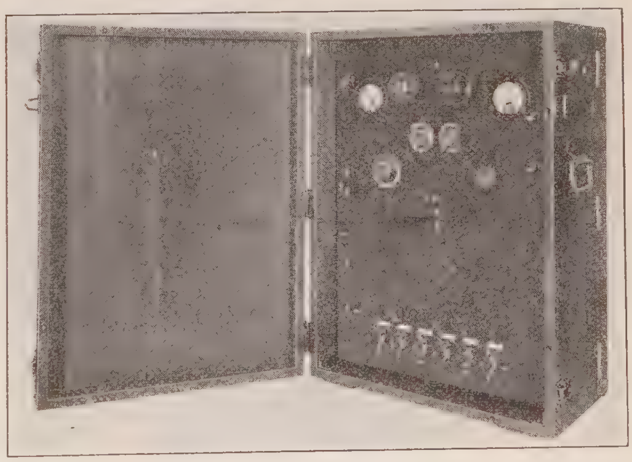

Fig. 24—Assembly of Experimental Radio Transmitter with Signaling and Talking Unit in Cabinet

signaling tests over short distances. As explained in the section describing the basic system, this transmitter has an output of about 5 watts at 200 to 450 meters.

Fig. 22 shows the assembly of one of the radio receiver units used in the tests. This is of the radio frequency amplifier type employing N tubes, such as would be employed in a commercial installation as in the Persian point-to-point system.

Fig. 23 shows the signal-receiving unit for automatic selective signaling. This includes the alternating-current relay, the selector mechanism and the necessary associated relays to respond to the incoming signal when connected to the detector tube of an ordinary radio receiver. This unit also includes an N tube amplifier for use when it is desired to secure the maximum signaling range. In this unit, terminals are provided on the rear of the panel in addition to the binding posts on the front, so that when the panel is removed from the box, rear wiring can be used if desired.

If it is desired to associate several panels together in one cabinet, each panel is detached from the box and mounted on the vertical supports which are provided in the standard cabinets. Fig. 24 shows the experimental radio transmitter together with the signaling and talking unit assembled in one of these standard cabinets which are designed to house equipment of any type mounted on standard panels. Fig. 25 shows the radio receiver and signal-receiving unit in a similar cabinet.

In some cases it may be desirable to mount the radio receiving apparatus, signal-receiving unit, signaling and talking unit and other associated apparatus together on one rack, without employing cabinets. Fig. 26 shows how this might be accomplished, the various panels of standard length being assembled on a standard rack suited to mount many different types of units employing

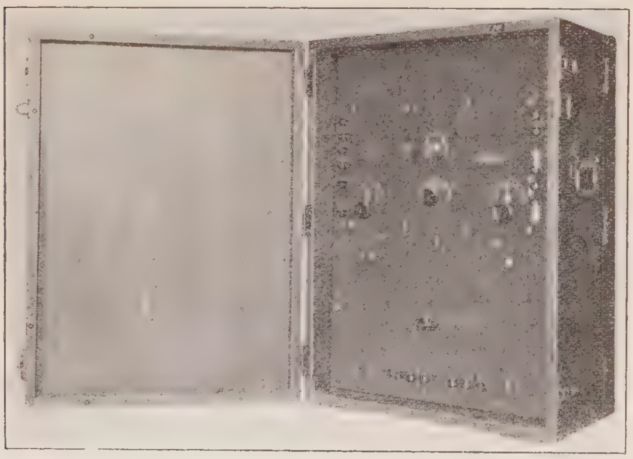

Fig. 25—Assembly of Radio Receiver and Signal Receiving Unit in Cabinet

this type of design. In this case, the radio transmitter is not included with the receiving apparatus, as it is assumed that in a commercial installation it may be of a larger and more powerful type than the experimental one previously shown for purposes of illustration. The 135-cycle interrupter is also shown as a separate unit, since such a separate interrupter may be required if the output of a small interrupter of the type which was included in the signaling and talking unit for convenience in the experimental work, is insufficient.

Review of System Characteristics

In considering the application to radio telephony of the signaling system which has been described, it is of interest to review certain of its outstanding characteristics. These may be briefly summarized as follows:

(1) The selectivity of the signaling system is such that interference of the kinds ordinarily experienced in radio telephony will make speech unintelligible before it will cause the signaling system to fail. Due to this high degree of selectivity, the signaling apparatus will operate if the radio system is adjusted so as to permit commercial transmission of speech, when the field strength is as low as it is desirable to use for the latter. With the types of radio apparatus which have been described, reliable operation of the signaling system has been secured with a field strength as low as 100 microvolts per meter.

(2) The sensitivity of the signal-receiving apparatus is such that the energy output obtainable from the smallest available types of vacuum tubes is more than sufficient to operate it satisfactorily. The type N vacuum tube can give an output of several hundred microwatts when operated as an amplifier, while the sensitive 135-cycle relay used in this signaling system will operate with as little as 30 microwatts.

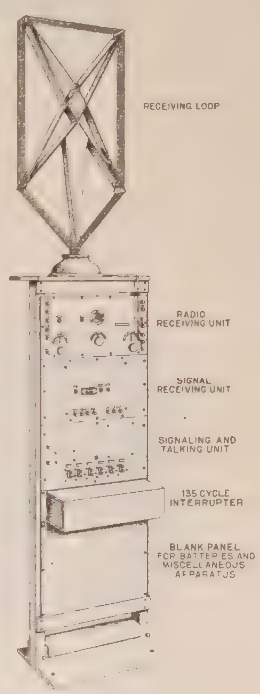

Fig. 26—Typical Assembly Arrangement for Panel Mounted Radio Receiving and Signaling Apparatus on Standard Rack

(3) The system readily permits automatic selective signaling, whereby any one station out of a number on the same wave length may be signaled separately, as well as being adapted to use where only one sending and one receiving station are concerned. Seventy-eight stations on one wave length may be signaled separately with the apparatus which has been described while by employing other apparatus of a similar type which is at present available, over 200 stations may be signaled separately. The system is also adapted to permit the simultaneous signaling of all of the stations which may be included in the system on one wave length.

(4) The form and arrangement of the signaling apparatus are practically independent of the type of radio service, the power capacity of the radio system and the wave length used. It is applicable to ordinary radio transmitters and receivers without requiring modification of the radio equipment, and at the same time is simple in form and not high in cost as compared with the remainder of the radio equipment.

The Limitations of Output of a Power System
Involving Long Transmission Lines

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Review of the Subject.*—The conditions of stability of a system are discussed and it is pointed out that while the various transmission line diagrams as used at present implicitly assume the terminal voltage at the two ends to be constant the degree of voltage regulation as determined by load conditions is an important factor in the determination of the limit of output. A type of combined diagram is proposed whereby this factor and other characteristics of the load may be included. The effect of the inherent regulation of synchronous condensers is taken up particularly with respect to compound transmission lines.*

A numerical example of a 300-mile line is considered and various characteristic curves are drawn. The relation between the maximum output and the capacity of condensers installed at the mid-point shows the benefit obtained by increasing the condenser capacity—within certain economic limits.

Mathematical analyses are presented to cover a number of different conditions.

General Considerations and Theory

The transmission of electric power over the long distances now considered practicable presents to the engineer a wide variety of problems for solution, some of which must be primarily economic, while others will be more strictly confined within the limits of the art. Even these purely technical problems are of radically different kinds; for instance, the necessity of the use of higher voltages results in questions of insulation and corona protection, the design of switching equipment, transformers, etc. The particular problem here considered, however, is of the capability of electric circuits of high relative impedance to deliver large quantities of power. This limitation due to impedance, becomes more prominent as the length of the lines increases and it is pertinent that methods of calculation be devised to represent as nearly as practicable the actual conditions under which a line may be expected to operate. This is the object of the present paper.

If the power demanded from a transmission system be in excess of its capability to supply, the connected apparatus at the receiving end will drop out of step and the system become inoperative. This limitation may be called the limit of output, the limit of stability or the point of pull-out. Methods of calculation of this condition based on transmission line constants and assumed voltages, or the diagrams usually substituted for these calculations, would give true results if the transmission line were the only link for the supply of power, but the electrical circuit of a transmission system comprises generators, transformers, transmission lines, synchronous condensers and the load circuit, and the limit of output will be determined by the combined effect of all of these. It may be said, therefore, that while the various transmission line diagrams as ordinarily employed give correct results as far as the definite inter-relations of power, voltage and current are concerned, the limits of output are only conventional values greater than the actual limits, and should be used only for comparative results in the case of important lines. It is possible, however, to combine the characteristics of the component parts of a power system to form a single diagram for the whole system. To make such a diagram complete becomes a much too complicated process, but it is believed that by including some of the more important factors, particularly the characteristics of synchronous condensers and of the load, a fair approximation may be made with only a justifiable amount of extra labor.

The methods presented in this paper are particularly applicable in determining the limit of output for "compound transmission lines"[1] by which is meant those lines employing synchronous condensers at intermediate stations for the purpose of voltage regulation. This type of line, recommended by Frank G. Baum,[2] promises to become of increasing importance due to the present tendency toward the development of the more distant sources of waterpower and the inter-connection of separated systems.

Before making a detailed study of the limits of output of power systems a general conception of stability of operation may be outlined. The principles involved are not advanced entirely as assumptions nor as hypotheses, but by presenting the phenomenon in this way the purpose of the various diagrams may be rendered clearer.

The characteristics of a transmission line as an electric circuit are closely similar to those of a synchronous machine, the main differences being the effect of magnetic saturation in the latter, and the much greater magnitude of the distributed capacity effect in the former. It will be found, in fact, that the various transmission line diagrams may be derived directly from the classic synchronous motor diagrams of Blondel. That the limit of stability of a line is physically re-

Abridgement of a paper presented at the Midwinter Convention of the A. I. E. E., Philadelphia, Pa., February 4-8, 1924. Complete copies to members on request.

1. The term "compound transmission line" has been introduced as conveying most nearly the conception of this type of line as given in the following discussion.

2. Voltage Regulation and Insulation for Large Power, Long Distance Transmission Systems, Frank G. Baum, Journal A. I. E. E., August, 1921.

lated to the pull-out of a synchronous motor is shown by the sudden and complete stalling of connected apparatus when this point is exceeded. When a synchronous motor is loaded, its rotor drops back in phase position by an angle governed by the synchronous impedance of the machine, the condition of stability being represented by the fact that an increase in angle results in an increase of torque. When the limit of stability is passed, the torque decreases with an increase in the phase angle so that this represents an impossible condition of operation. The point of transition between the two conditions occurs when the phase angle is approximately 90 electrical degrees, or more strictly, $\theta = \tan^{-1} x/r$ which may be referred to as the angle of pull-out. Similarly, the conventional limit of stable operation of a transmission line is reached when the phase angle between the sending and receiving ends has reached the corresponding value ($\tan^{-1} x/r$). This angle it will be noted is a "line constant" in both cases and is entirely independent of the values of voltage assumed.

While the angle of pull-out may be used as the fundamental expression of stability some of its accompanying relations are found to form a more convenient means of investigation in more complicated circuits. Thus in studying a simple reactive tie line with constant voltages at either end, it is found that the voltage as measured at any intermediate point will drop as the phase angle between the two extremities increases. When the pull-out angle is reached the rate of voltage change with load must be infinite. Expressing this in mathematical terms; when $\theta = \tan^{-1} x/r$, then $\frac{\delta \text{ voltage}}{\delta \text{ load}} = -\infty$ at any intermediate point. This has assumed that the terminal voltages do not change with load; if this condition does not exist the rate of voltage decrease will be greater over the whole line and pull-out will occur at an angle less than $\tan^{-1} x/r$ and at a correspondingly smaller load. In other words, the output limit is determined not only by the actual voltage values at the line terminals at the instant of pull-out, but also by the degree of their regulation. With this idea in mind the difference between the conventional and actual output limitations may be more definitely explained. Transmission line diagrams assume constant voltages at the sending and receiving ends so that the output limit or maximum power so derived will represent only this ideal condition. Actually, the voltage regulation is not perfect at either end of the line, and the conventional value will not be realized.

This naturally brings up the question of the effect of automatic voltage regulators as used on generators and synchronous condensers to maintain constant voltage at both ends of the line. The response of voltage to the action of regulator contacts is much too sluggish when compared with changes of phase displacement due to load to allow the vibrating regulator to be considered in a different sense from a rheostatic regulator operating with occasional adjustment and therefore their use will not modify appreciably the analysis of stability as given above. If a vibrating regulator of a much quicker degree of response were devised an entirely different state of stability might be reached. This may be considered as follows,— when the actual limit of stability is reached a condenser at the end of the line will commence to drift out of step at a rate determined by the excess load, and the voltage will drop correspondingly. A sudden increase in field excitation materially increasing the voltage would bring the rotor and voltage phase angle back again tending to cause an overshoot in the forward direction and consequent high voltage. A reduction of field current will result in the initial condition being regained, followed by the repetition of the cycle. This represents a state of artificial stability in which, with a quick enough response, it would be possible to reach the conventional output limit, or the equivalent of perfect voltage regulation would be obtained. This theory of artificial stability, although perhaps not a practical possibility, is here outlined mainly for the purpose of preventing any misconception regarding the capabilities and limitations of the commercial vibrating regulator in connection with the present subject. Moreover, if the state of artificial stability were attainable it is very doubtful that it would be desirable to depend on this apparatus as the main link in maintaining the operation of the system. In deriving the limit of output for power systems it may be considered that the condensers are operating under a definite value of excitation for each value of load, this value being adjusted by the regulator as the load conditions change.

The general conception of stability may be considered in connection with the theory of compound lines. It has been stated that if the voltages at two points in a circuit are perfectly regulated the limit of stability occurs when the phase angle between the two points equals $\tan^{-1} x/r$, this being independent of the remainder of the circuit. Applying this to the compound line it will be seen that if the voltage regulation at every condenser station be considered perfect the limit of stability is that of the individual sections of line. Adding sections of line will not reduce the output except by the losses in the sections themselves. Actually, of course, the inherent regulation characteristics of the condensers used are finite and the actual output limit of a compound line must be somewhere between the value of the "weakest" section as referred to above and that of the complete line neglecting the intermediate condensers. To accurately evaluate such a line the actual regulation characteristics of the condensers used must be combined with the line diagram.

The synchronous condenser has inherently very desirable characteristics from the standpoint of voltage regulation; it forms a kind of reservoir of magnetization by delivering magnetizing current to the line in in-

creased amounts as the voltage falls. The rough mathemtaical expression for the characteristic of a condenser with constant excitation is as follows:

$$I_o = \frac{E_c - E_r}{X_c}$$

I_o = magnetizing current.
E_c = open-circuit voltage of condenser.
E_r = applied terminal voltage.
X_c = synchronous impedance of condenser.

If a condenser be small, the regulation will be poor and its effect towards increasing the capabilities of the compound line will be limited. Considering, on the other hand, the hypothetical case of a condenser of infinite capacity, X_c will equal zero and the inherent regulation must be perfect, and in the case of the compound line the limit of stability would be truly that of the "weakest" section alone. This comparison demonstrates clearly the importance attached to the choice of condensers for such applications.

In the above connection it may be noted that static condensers are inherently unsuitable for the regulation of long lines. Their inherent characteristics may be expressed thus,

$$I_o' = E_r' X_r'$$

which signifies that the magnetizing current decreases with the voltage, the effect on regulation being therefore negative. This same argument applies to the distributed capacity of the line itself.

The subject of stability might be examined from one other angle. In a paper before this Institute[3] it has been inferred that if the load on a transmission line could be maintained at a certain critical value, the distance to which the power might be transmitted is limited only by the line losses. On examining the examples given from the standpoint of stability it was found that the conventional limit of stability occurred at the distance of one quarter wave length. It may be stated then that even for the restricted conditions considered the use of synchronous condensers at intervals of a few hundred miles would be a necessity, not to change the voltage conditions, for they might be merely floating on the line without carrying reactive current, but to reduce the relation $\dfrac{\delta \text{ voltage}}{\delta \text{ load}}$ along the line and thus maintain the stability of the system.

Line Diagram

In dealing with long distance transmission lines it has become the recognized practise to treat the effects of distributed capacity by means of hyperbolic functions. The conventional vector equations may be written.[4]

$$E_s = E_r \cosh \sqrt{Z\,Y} + I_r\, Z \frac{\sinh \sqrt{Z\,Y}}{\sqrt{Z\,Y}} \qquad (1)$$

$$I_s = E_r\, Y \frac{\sinh \sqrt{Z\,Y}}{\sqrt{Z\,Y}} + I_r \cosh \sqrt{Z\,Y} \qquad (2)$$

E_s and E_r are respectively the voltages at the sending and receiving ends, and I_s and I_r the corresponding values of current. Z is the total line impedance, and Y the admittance. All quantities are complex.

These expressions may be abbreviated to the form[5]

$$E_s = A\, E_r + B\, I_r \qquad (1a)$$

$$I_s = C\, E_r + A\, I_r \qquad (2a)$$

and rearranging—

$$E_r = A\, E_s - B\, I_s \qquad (3a)$$

$$I_r = -\, C\, E_s + A\, I_s \qquad (4a)$$

where

$$A = \cosh \sqrt{Z\,Y}$$

$$B = Z \frac{\sinh \sqrt{Z\,Y}}{\sqrt{Z\,Y}}$$

$$C = Y \frac{\sinh \sqrt{Z\,Y}}{\sqrt{Z\,Y}}.$$

The relation of the above formulas to those for the simpler short lines may be noted by assuming the distributed capacity Y negligible. Under this condition $\cosh \sqrt{Z\,Y}$ and $\dfrac{\sinh \sqrt{Z\,Y}}{\sqrt{Z\,Y}}$ both become equal to unity. Then $I_s = I_r$ and $E_s = E_r + I_r\, Z$ which is the familiar expression for the simple circuit.

A simple voltage vector diagram may be drawn, very convenient for the purpose in hand, directly from equation (1) – or (1a). This diagram has already been published several times and in some cases expanded in an elaborate manner.[6]

For convenience in graphical construction and algebraic analysis the line constants may be written in form

$$A = A_1 + j\, A_2$$

$$B = B_1 + j\, B_2$$

$$C = C_1 + j\, C_2$$

3. "Qualitative Analysis of Transmission Lines," H. Goodwin, Jr. Journal A. I. E. E. January, 1923.

4 See Chap. 15 "Transmission Line Formulas," H. B. Dwight. D. Van Nostrand & Co., etc., for the derivation of these expressions.

5. For the development of these expressions to include unsymmetrical lines and combined lines and transformers, see companion paper "Power Limitation of Transmission Systems," R. D. Evans and H. K. Sels.

6. A Graphic Method for the Exact Solutions of Transmission Lines," Holladay, Journal A. I. E. E., Nov. 1922; also "Calculs, diagrammes et régulations des lignes de transport d'énergie à longue distance." Thielemans, Revue Générale d'Electricité, September 25, 1920 and following: etc.

while as a scalar quantity—

$$B = \sqrt{B_1^2 + B_2^2}$$

Similarly I_r and I_s may be resolved into their power and wattless components

$$I_r = I_{rw} + j\, I_{ro}$$

$$I_s = I_{sw} + j\, I_{so}$$

I_{rw} and I_{sw} being in phase with E_r and E_s respectively.

The general construction of the voltage diagram using E_r as a datum of reference is shown in Fig. 1.

From the geometrical construction it is evident that with E_r assumed constant and considering only the power component of current, $(I_{ro} = 0)$, the locus of E_s must lie on the line $T\,S$, while for any given power component of current, varying the wattless component will merely move the locus of E_s along a line perpendicular to $T\,S$,—the line $G\,H$, for instance. With these relations in mind it may be seen that the lines $T\,S$ and $T\,K$ may be utilized as the axes of the two components of current, or if preferred, of kilowatts and reactive kv-a. The former is utilized mainly in the following discussion.

Considering further the geometrical relations of Fig. 1 it is obvious that E_s' is the minimum value of voltage at the sending end which will sustain a load at the receiving end corresponding to the point S, and conversely that with the voltage E_s' this load represents the maximum value, or remembering that the voltages are taken as constant this will represent the conventional limit of stable operation of the transmission line. E_s' is parallel with $T\,S$ so that this point will occur when the phase angle between the voltages at the two ends of the line is equal to $\tan^{-1} B_2/B_1$ which is the equivalent of $\tan^{-1} x/r$ of either the simple circuit or of the synchronous machine. This angle as mentioned before is purely a line constant.

From Fig. 1 can be obtained E_r, E_s, I_r, the power factor at the receiving end, and the voltage phase angle θ. With a slight complication I_s and its phase angle with E_s may be included as well. Thus, from equation (3a)

$$B\, I_s = A\, E_s - E_r \tag{5}$$

In Fig. 2 $O\,L = (A_1 + j\, A_2)\, E_s$ and $L\,V = (B_1 + j\, B_2)\, I_s$. By using the same reasoning as for Fig. 1, I_{sw} is found to be along the axis $L\,W$ and I_{so} at right angles to it. The current values can be measured on the same scale as I_{rw} and I_{ro}. If kw. and reactive kv-a. are desired, the scale will differ from the corresponding one at the receiver end by the ratio E_s/E_r. The value of power-factor at the two ends of the line may be taken as $\cos\phi_r$ and $\cos\phi_s$ respectively. The line efficiency may be obtained from the quantities given by a short numerical calculation.

Although usually more convenient, it is not necessary to resort to graphical methods to determine certain conditions of operation. Certain expressions which are particularly convenient as occasional checks on graphical results are given below. Their derivation will be found in the Appendix.

For the conventional point of pull-out, $\theta = \tan^{-1} x/r$

$$I_{rw} \text{ (pull-out)} = E_s/B - M\, E_r \tag{6}$$

$$P_r \text{ (pull-out)} = E_r\, (E_s/B - M\, E_r) \tag{7}$$

where P_r is power at the receiving end in watts per phase assuming E_r to be the voltage to neutral.

$$M = \frac{A_1\, B_1 + A_2\, B_2}{B^2} \quad \text{(a line constant)} \tag{8}$$

These quantities are all scalar. With the same conventional assumptions of perfectly constant terminal voltages it is possible to derive additional relations. In the case of a direct-current circuit it will be remembered that the power flow into any part of the circuit is a maximum when the voltage across this part is equal to one-half the total voltage or $E_r = E_s/2$. For a transmission line the equivalent condition is found to be represented by the expression

$$E_r = \frac{E_s}{2\, M\, B} \tag{9}$$

for which condition

$$I_{rw} \text{ (maximum pull-out)} = \frac{E_s}{2\, B} \tag{10}$$

$$P_r \text{ (maximum pull-out)} = \left(\frac{E_s}{2\, B}\right)^2 1/M \tag{11}$$

In investigating the significance of these equations it will be found that the limit of output is a maximum in the case of a normal 60-cycle line when the receiver voltage is considerably higher than the sending, although it is true that on account of the large condenser capacities required for such voltage relations this will not represent an economical condition of operation. For lines of 25 cycles and less it will probably be found that the maximum output of the line will be obtained when E_s is raised appreciably higher than E_r. In the case of the higher frequency lines more accruate assumptions as regard voltage regulation will naturally tend to change these relations somewhat, particularly when the condenser is such a large factor in the result. When lines are operated so that E_r is greater than the critical value $\dfrac{E_s}{2\, M\, B}$ it is found, as expressed in some of the following diagrams, that the actual and conventional limits of stability coincide; that is, the line actually pulls out with the angular displacement equal to $\tan^{-1} B_2/B_1$

The reactive component of current at the receiver end, I_{ro} may also be expressed in mathematical form.

$$I_{ro} = E_r\, K \pm \sqrt{(E_s/B)^2 - (P_r/E_r + E_r\, M)^2} \tag{12}$$

K being an additional line constant of the value

$$K = \frac{A_1\, B_2 - A_2\, B_1}{B^2} \tag{13}$$

The quadratic equation (**12**) will have two real solutions, a singular solution, and imaginary solutions. These may be interpreted from Fig. 1 as follows,—the smaller real solution (that of minus sign) will represent the condition of stable operation, ($\theta < \tan^{-1} B_2/B_1$), and the greater solution (that with plus sign) will represent the unstable zone where $\theta > \tan^{-1} B_2/B_1$. The singular solution corresponds to the point of pull-out, $\theta = \tan^{-1} B_2/B_1$. The imaginary solutions are for conditions where the conventional pull-out load is exceeded. For the singular solution equation (**12**) may be expressed.

$$I_{ro} = K\, E_r \qquad (\mathbf{14})$$

which shows that the value of reactive current at the conventional point of pull-out is a direct function of the receiver voltage and independent of the other conditions of operation.

Equations (**12**) and (**14**) represent only the reactive current in the line itself; to obtain the total condenser current there must be added to I_{ro} the magnetizing current required by the load as estimated at this same point. A synchronous condenser must be chosen on the basis of the algebraic sum of the two.

The System Diagram

The preceding diagram may be properly applied only to the transmission line. To define the limiting conditions of operation of a transmission system the characteristics of the line must be combined with those of the rest of the circuit. In this respect, the line transformers represent no particular difficulty, their concentrated

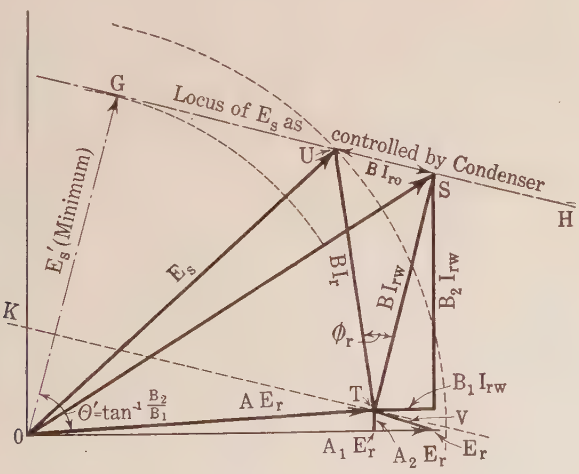

Fig. 1—Voltage Vector Diagram of a Transmission Line

impedances may be included with that of the line and a set of line constants derived by the method already referred to. The diagram of Fig. 1 will then represent the line with transformers. Due to the fact that many of the assumptions made in transmission line calculations must necessarily be rather broad approximations it may not be entirely necessary to take into account the magnetizing current of the transformers. If the necessary data for this is available, however, it should be combined with the characteristics of the adjacent synchronous condenser. The magnetizing current and the condenser currents result from shunt admittances at the same point of the circuit so that the above suggestion is technically correct. The magnetizing current decreases at a considerably faster rate than the transformer voltage so that it will add very slightly to the stabilizing effect of the condenser station. In the case of the transformers at the sending end the main effect of the magnetizing current is a very slight increase in the

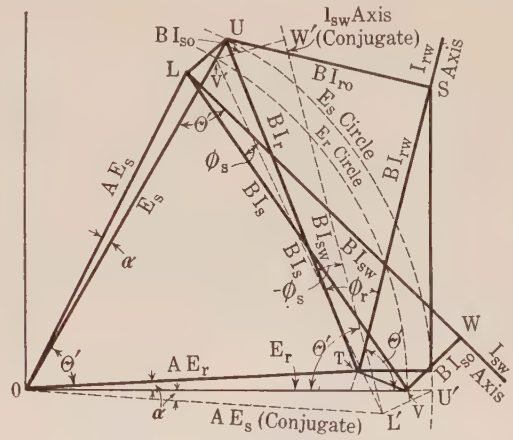

Fig. 2—Diagram Including Current Relations at Sending End

field current of the generators and may be otherwise neglected.

In the following discussion the effect of the inherent voltage regulation of the main generators has been neglected. This is justified on the grounds that the error is slight while the labor involved would increase greatly. Two methods, almost equally laborious may be used in taking this factor into account; one is the ordinary method for the compound line, while the other is an extension of the method used for transformers. The synchronous impedance of the generator may be added to that of the transformer at the sending end and a diagram used for the line transformers and generator. The "sending voltage," *i. e.*, the internal voltage of the generator, becomes a variable and a separate diagram must be worked out for each value of excitation while in addition these diagrams must be correlated with the conditions at the actual sending terminal of the line. Both of the above methods become somewhat complicated.

The effect of the load on the limits of a transmission line is important and its characteristics should be approximated with a fair degree of accuracy. For this purpose two general classes of loads may be considered; first where the power required is independent of voltage, and second, where the power required decreases with voltage. The rotating machine where the output is determined by frequency is typical of the first class, while a lighting or heating load where the power varies with the square of the voltage is typical of the second.

The actual load of a system is a combination of a large number of units of both of these classes, with possibly other classes less clearly defined in addition. The rotating load is usually of preponderant value although the component of lighting load will produce some tendency for a decrease with voltage which may be estimated when the relative proportions have been determined.

Due to the importance of the constant power type of

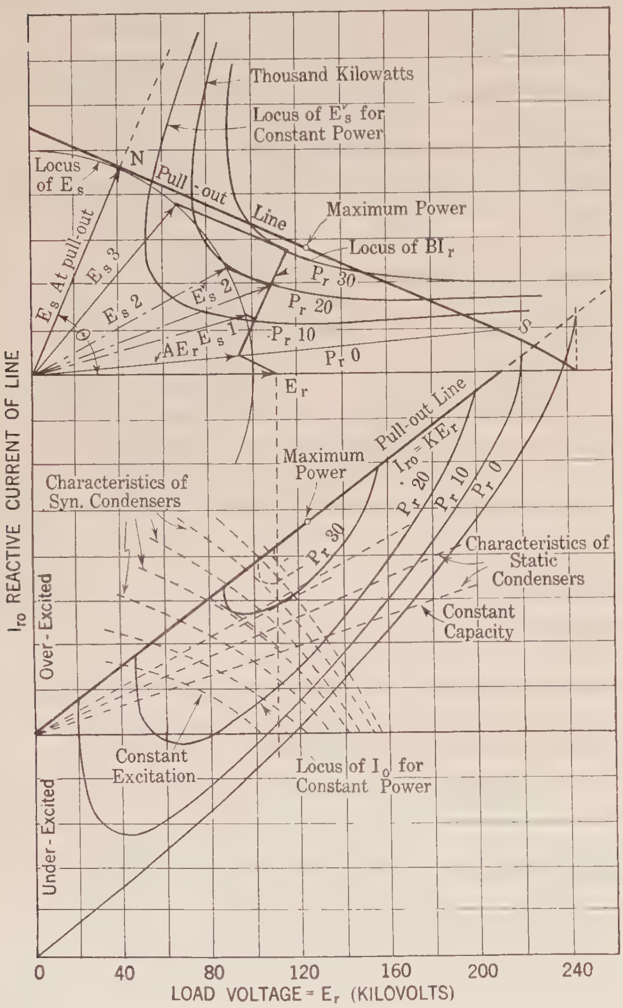

Fig. 3—Transmission Line Diagram. Diagram of Voltage Vectors

Constants $A_1 = 0.85$
$A_2 = 0.075$
$B_1 = 168$
$B = 183$

Fig. 3a—Reactive Current Curves Derived from Voltage Diagrams

load its characteristics may be studied in some detail. It may be noted then, in Fig. 1, that if the power component of current I_{rw} be varied inversely with E_r the locus of the point S, $(O\,S = A\,E_r + B\,I_{rw})$, will be a hyperbola with the lines $O\,T$ and $O\,G$ as asympotes. The hyperbolas for various values of P_r are shown in Fig. 3, the various vectors corresponding with those of Fig. 1. The reactive components of current are indicated by the intervals measured parallel to the line $N\,S$ and between the hyperbolas and the circular locus of E_s. The zone of stable operation considered on the conventional basis is then represented by the triangle $N\,O\,S$, $N\,S$ being designated as the "pull-out line." One hyperbola may be drawn which will just become tangent to the pull-out line; this represents the condition of maximum output expressed by equation (**11**). It may be observed that in consequence of the locus E_s becoming tangent to the line $N\,S$ the rate of change of reactive current, $\frac{\delta\ I_{ro}}{\delta\ E_r}$, is infinite for the condition of pull-out.

Although the conditions of stability may be readily visualized from Fig. 3, it will be found much more convenient for actual calculations to replot the data as in Fig. 3a. These curves show the relation between power, voltage, and reactive current at the receiving end. The characteristic curves are slightly similar in form to the V-curves of a synchronous motor although plotted on a somewhat different basis. The curves represent the requirements of reactive current for the different conditions of operation, so if the regulation curves of the synchronous condenser, representing the reactive current capable of being furnished under various conditions of voltage and excitation, be plotted with reference to the same axes, the intersections of the two sets of curves gives resultant points of operation of the combination. An additional assumption is made that the load is of unity power-factor.

Assuming the condenser to be operating with constant excitation the limit of output occurs where the two sets of curves would become mutually tangent. Thus, it is noted that the $P\,r = 30$ curve becomes tangent to one of the condenser regulation curves at 90 kilovolts. According to the theory already advanced, if the condenser were furnished with a vibrating regulator set to maintain 90 kilovolts on the line the limit of output would be identical with the above, even assuming the load to be free from fluctuations. The conventional limit, where the various P_r curves cross the pull-out line would indicate this load to be stable until the voltage decreased to 86 kilovolts. These curves show definitely how the actual limitations of a line depend upon the condenser characteristics, and furthermore that the static condenser does not have the proper inherent characteristics for transmission line regulation. These relations may be better appreciated by referring to Fig. 4 which is derived from Fig. 3a. Here a comparison is presented between the conventional limit, the limit with a condenser of finite characteristics, and the limit with a static condenser for line regulation. It will be noted that the various limits converge to the critical point where $E_r = \frac{E_s}{2\,M\,B}$ (**9**). At this point and above, pull-out must occur where $\theta = \tan^{-1} B_2/B_1$ so that it may be deduced that in the case of low-fre-

quency lines where the normal voltage relations will approach those of equation (9) the conventional line diagram will give reasonably accurate results for steady loads, although such will not be the case for lines of higher frequency as is shown in the later examples.

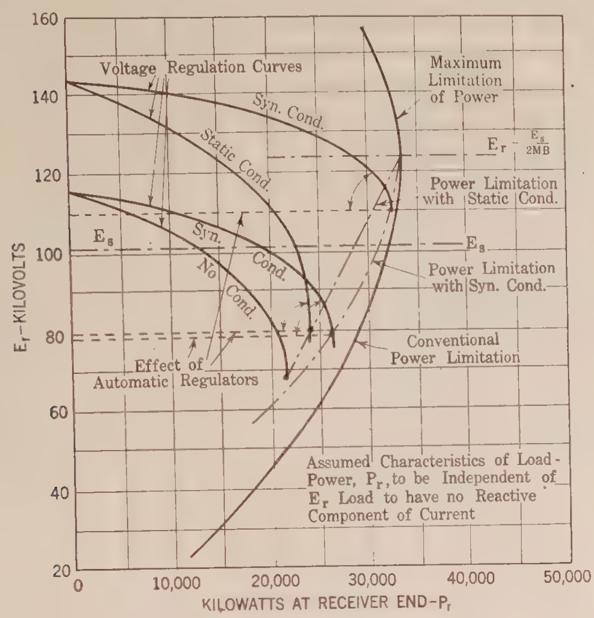

FIG. 4—COMPARATIVE LIMITS OF OUTPUT

In combining the line and condenser characteristics in Fig. 3A the reactive component of the load has been neglected; Fig. 5, however, shows the combination of the line characteristics with those of a synchronous motor at constant excitation. The intersections of

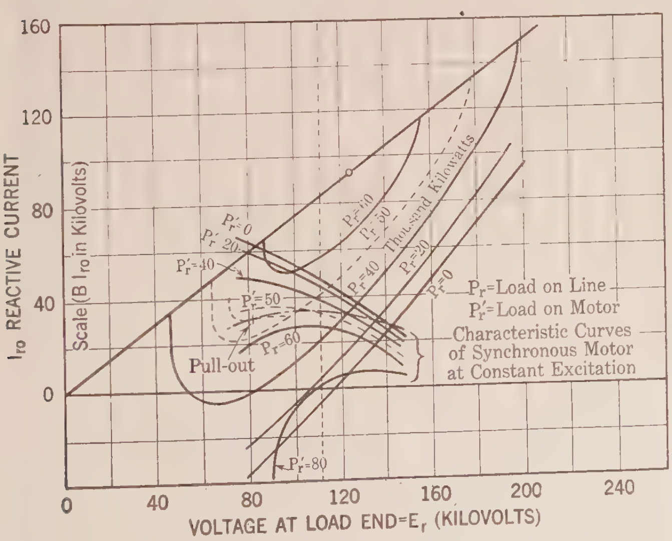

FIG. 5—COMBINATION OF A TRANSMISSION LINE AND A SYNCHRONOUS MOTOR LOAD, THE LATTER WITH CONSTANT EXCITATION

I_0 = Reactive Current

corresponding curves giving the points of operation, the limiting condition being as before the point of mutual tangency of the two sets of curves. To indicate the effect of a synchronous condenser on the above combination its curves would have to be added to each one of the load characteristic curves. This will be taken up more in detail in connection with the study of compound lines. Incidentally, the close similarity between the characteristics of the synchronous motor and those of the transmission line may be noted in Fig. 5.

To pass now from the constant power type of load, Fig. 6 has been drawn to represent a load of constant current, a state somewhere between a motor load and a lighting load. Fig. 6A shows that the actual limit of output will always coincide with the conventional value

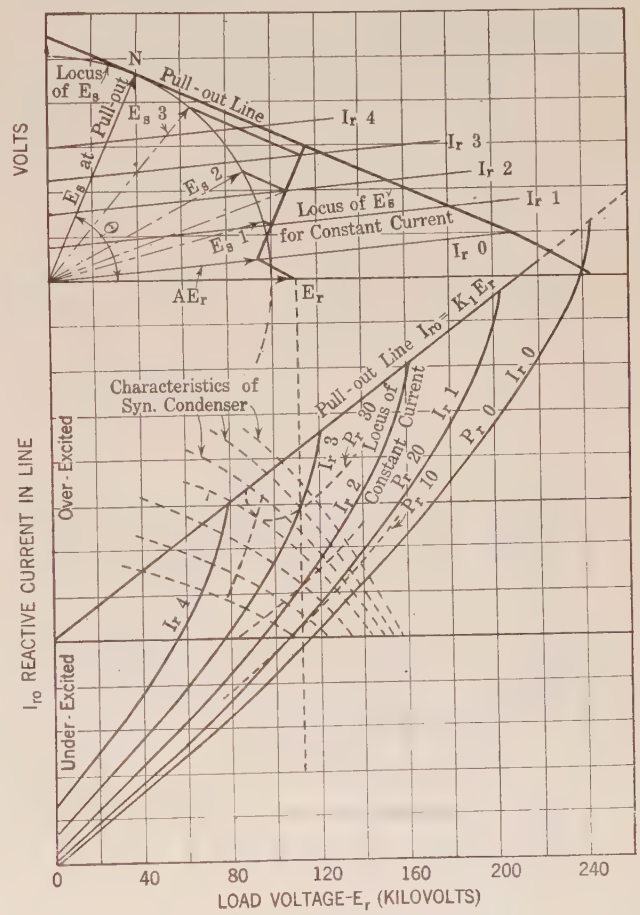

FIG. 6—TRANSMISSION LINE DIAGRAM. DIAGRAM OF VOLTAGE VECTORS

Constants A_1 = 0.85
A_2 = 0.075
B_1 = 73.1
B_2 = 168
B = 183

FIG. 6A—REACTIVE CURRENT DIAGRAM DERIVED FROM FIG. 6

just as in the case of the constant power load when E_r is greater than $\frac{E_s}{2\ M\ B}$. The above condition, it should be noted, will not hold necessarily in the case of a compound line for the inherent characteristics of the load are masked to some extent by the effect of the condenser at the receiving end. In general, such a load is very favorable from the standpoint of stability.

The regulation curves of the synchronous condenser depend upon the rated capacity of the machine and upon the various design features involved. The curves may be obtained in the ordinary way from the load saturation curves at zero power factor[7] with the exception that the condensers will always be connected to the transmission lines through transformers, the impedance of which will modify their characteristics as considered with respect to the line. This effect is equivalent to an increase in the armature reactance of the condenser, so that corrected load saturation curves may be drawn by increasing the reactance component of voltage drop by the reactance drop in the transformer. This method was employed in obtaining the data for Fig. 7. When the relation between magnetizing current and voltage is known for the transformer this current can be subtracted from the corrected condenser current at corresponding voltages, the result being a complete regulation curve for the condenser and transformer.

It may be remarked that the increased impedance due to the transformer has a material effect on the regulating action of the condenser and that it should be reduced as low as is practicable. The operating experience obtained with such transformers of high impedance fully verifies this conclusion.

In connection with the operation of automatic voltage regulation one further limitation may be mentioned. The operation of the regulator is only possible up to the point where the full exciting voltage is impressed across the condenser field winding, at which point the regulator contacts become blocked in the closed position. If the requirements from the condenser are still increased the machine operates with constant maximum excitation, the voltage dropping as the load increases. On account of economic considerations involved in the application of condensers this point of maximum current will usually be reached considerably before the limit of output. Therefore pull-out should occur with constant excitation on the condenser.

Compound Transmission Lines

The compound transmission line can probably be studied best by means of an actual example where the quantitative factors are directly involved. Consider then a 300-mile transmission line with a condenser station at the mid-point. Actually the condenser would be somewhat more beneficial if placed slightly closer to the sending end.

The following are the data on the assumed line:
Complete line
Length of line, 300 miles.
Conductors, 500,000 cir. mil aluminum cable.
Spacing—15 ft. effective spacing 18.9 ft.
Voltage between conductors 150,000 volts (86,600 volts to neutral).

7. See Section 4394 of A. I. E. E. Standards, 1922, etc.

Derived constants for 300 mile line.

$A = 0.807 + j\,0.043$ $\quad A_1 = 0.807$
$B = 48.7 + j\,229$ $\quad A_2 = 0.043$
$C = (-\,0.0228 + j\,1.52)\,10^{-3}$ $\quad B_1 = 48.7$
$K = 3.33 \times 10^{-3}$ $\quad B_2 = 229$
$M \doteq 0.913 \times 10^{-3}$ $\quad B = 234$

Derived costants for each 150 mile section.

$A = 0.9507 + j\,.0112$ $\quad A_1 = 0.9507$
$B = 27 + j\,120.6$ $\quad A_2 = 0.0112$
$C = (-\,0.0036 + j\,0.80)\,10^{-3}$ $\quad B_1 = 27$
$K = 7.51 \times 10^{-3}$ $\quad B_2 = 120.6$
$M = 1.78 \times 10^{-3}$ $\quad B = 123.5$

For the purposes of the present discussion the impedance of the line transformers has been neglected, mainly so that the two line sections may be considered to be identical. When this factor is included the above constants will merely suffer some modification. For accurate line calculation it should be included.

The characteristics of a 25,000-kv-a. synchronous condenser combined with a transformer of 8 per cent

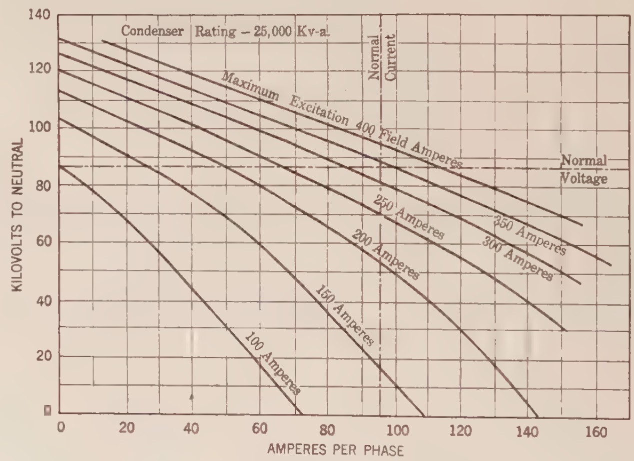

Fig. 7—Voltage Regulation Curves of Synchronous Condenser and 8 Per Cent Reactance Transformer

reactances is shown in Fig. 7. The effect of the magnetizing current of the transformers has been neglected, although if desired this can be taken into account by the method already referred to. Although condensers of various ratings are introduced into the discussion the regulation characteristics of all are assumed to vary with these curves proportional to the rating assumed for the condenser.

For the first set of data discussed the voltages at both the sending and receiving ends of the line have been assumed constant. For the receiver voltage this means that it is unnecessary to make any assumptions regarding the change of load with voltage. The limit of output may then be obtained from equation (7), or

$$P_r = 86{,}600\,(86{,}600/234 - 0.913 \times 86.6) \qquad (15)$$
$$= 25{,}200 \text{ kw. per phase or } 75{,}600 \text{ kw. total.}$$

This is the conventional limit of the 300-mile line without intervening condensers. When a condenser of finite capacity is placed at the middle point of the line, a type of diagram similar to Fig. 5 must be employed.

Assuming various values of voltage at the middle condenser A, from a diagram similar to Fig. 1 there may be worked out for each value of load at the receiver end, the power and reactive current at A. Also with a diagram such as Fig. 3 the conditions of voltage, power and reactance current may be worked out for the sending section of the line. Due to the discrepancy between the power at the point A and the point B these two sets of data may, for conveneince be plotted up together in the form of Fig. 8. Here the full line and dot-dash curves represent the receiver section of the line and the dotted curves represent the sending section. With a

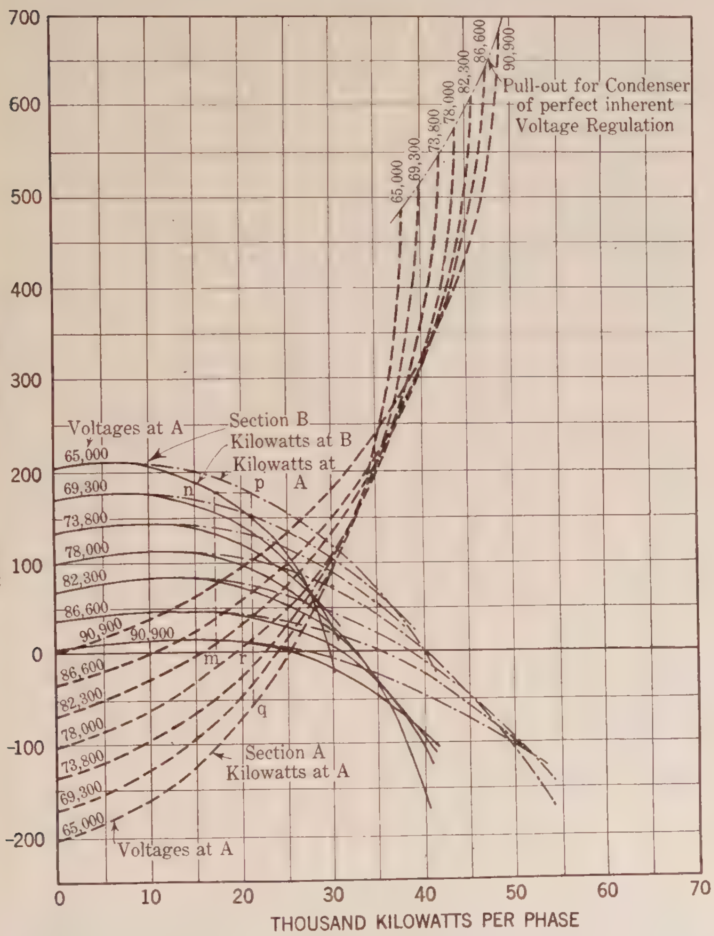

Fig. 8—Conditions at Mid-Section of Line for Determining Condenser Capacity Required

load at the receiver end corresponding to $o\,m$ the line loss in the receiver section will be $n\,p$. The reactive current furnished to the station A will be $r\,p$ while that required for the sending section will be $-\,r\,q$, the net result being that there is an excess of magnetizing current at A of the amount $p\,q$. These data may then be plotted as shown in Fig. 9, the full lines representing the characteristics at the point A for the whole line. The intersections of these curves with the condenser regulation curves give the points of operation of the combination of line and condensers. By employing different condenser curves the effect of the choice of condenser is readily apparent. Fig. 10 gives the voltage regulation curves at the station A assuming condensers of various sizes to be employed. The point

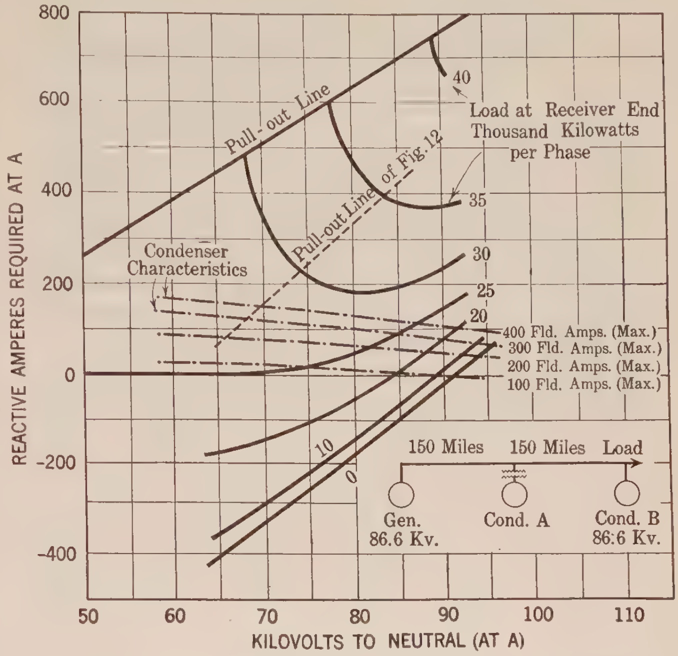

Fig. 9—Relations between Current and Voltage of the Mid-Point of a 300-Mile Transmission Line Receiver Voltage Constant

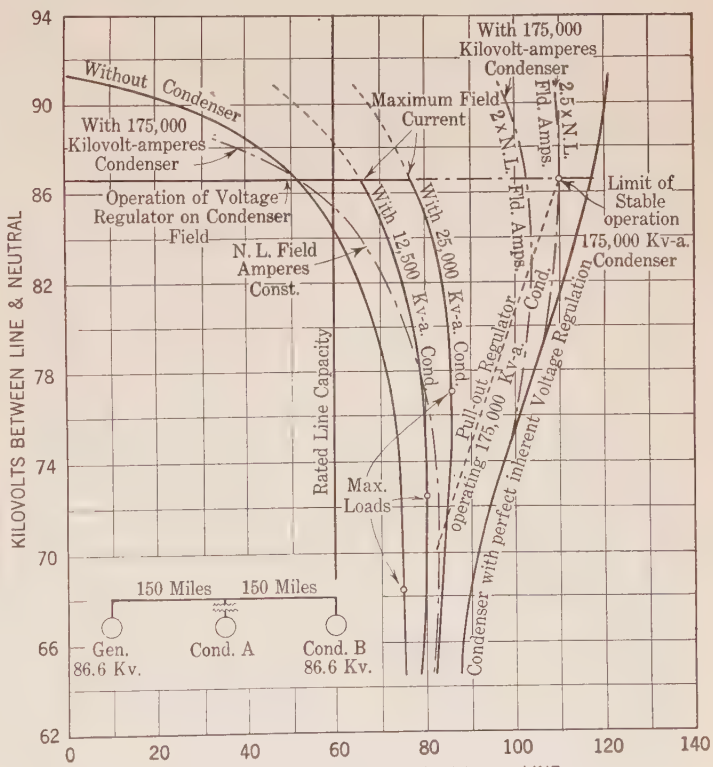

Fig. 10—Characteristics of Voltage and Load at Middle Point of 300-Mile Transmission Line

at which the voltage regulators become blocked is shown as well as the load and voltage at which pull-out occurs.

In connection with Fig. 10 it may be interesting to

note that although the 175,000-kv-a. condenser is sufficiently great in capacity to allow the regulator to operate completely up to the pull-out line at 86,600 volts, the inherent characteristics of the machine result in the limit of stability occurring at 110,000 kw. instead of the conventional 117,000 kw. Fig. 10 is of the same type as Fig. 4.

Fig. 11 has been plotted to show the relationship existing between the limit of output of a compound line and the size of the condenser used. It will be noted that to transmit the maximum amount of power over a line must become very uneconomical even if examined no farther than from the standpoint of the capital cost of synchronous condensers.

A final and rather elaborate study was made of this compound transmission line on the assumption that the condenser at the point B was finite in its characteristics. Two condensers, (a total of 50,000 kv-a.), each with characteristics represented by Fig. 7 were placed at this point while the load was assumed to be independent of voltage and at a constant power-factor of 90 per cent. The amount of labor resulting from this change was several times greater than before, the line being equivalent of a compound line of three sections. It is believed, however, that it may be possible to reduce this labor very considerably by using kinematic devices to represent the line characteristics. Fig. 12 is the diagram, resulting from this study, it is of the same general character as Fig. 9 although the limits are still further reduced. The above assumptions made concerning the load characteristics are only roughly approximate. If, for instance, the load is made up of 70 per cent rotating load and 30 per cent lighting load the increase of current with the decrease of voltage will be roughly half as great as in the case of constant power, which would tend to increase the stability. The assumption of the power factor being independent of load is probably not greatly in error. In a highly diversified load, where both synchronous and induction motors may be operated at various fractions of their ratings their effect on power factor with a change in voltage may be largely equalized. Where closer approximations of the load may be made the hyperbolic loci may be modified to correspond, an instance of which is given in Fig. 6.

The results of Fig. 12 have been included in Fig. 11 so that the error made in assuming a constant voltage at the receiving end is indicated as the difference between the two curves. With a 25,000-kv-a. condenser at the station A in each case the limit of output is reduced from 86,000 kw. to 75,000 kw.

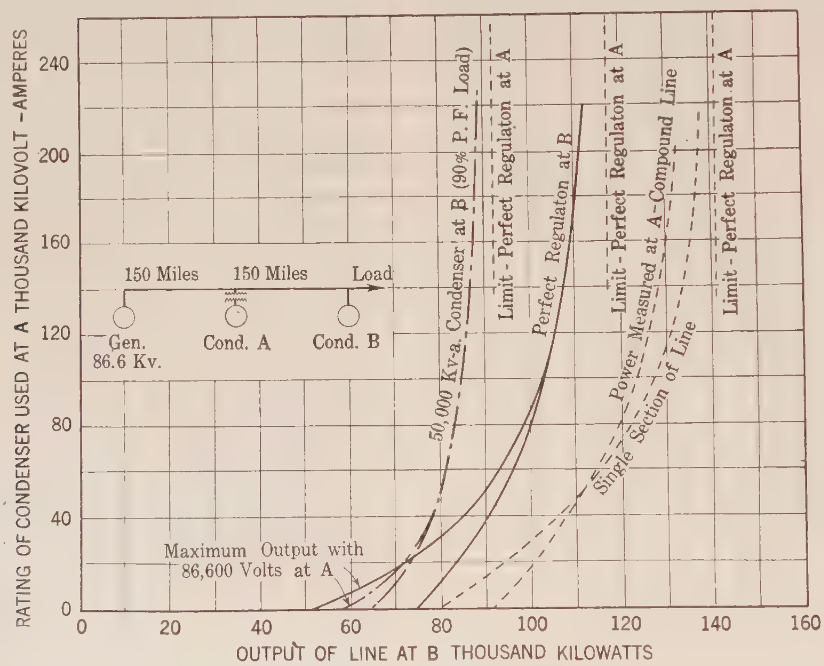

Fig. 11—Limits of Output of a Compound Transmission Line as Determined by the Condenser Characteristics

Summary

In the foregoing pages a method for determining some of the limitations of transmission systems has been developed in accordance with the conception of operation outlined, representing as nearly as practicable, it is believed, the actual conditions under which such a system will operate. In using this method it is essential that the characteristics of the apparatus connected to the transmission line, such as synchronous condensers and transformers, shall be accurately known as well as those of the line itself, and that reasonable approximations should be made regarding the characteristics of the load even when it is diversified. While this may often involve tedious complications the greatly increased accuracy of transmission line computations will much more than justify its use, if not making it almost a necessity in the case of compound lines.

The comparison of the various types of calculations

given in Fig. 11 shows the importance of the more complete methods for these lines and how the maximum rating of a line may be increased by adding to the condenser capacity at the various stations. Beyond some point, however, the condenser capacity must increase rapidly for an increase of load. Such curves will furnish new data for the economic study of transmission systems.

A conclusion has been drawn that static condensers are not inherently suitable for line regulation even though their cost might compare favorably with that of the synchronous machine. The vibrating regulator

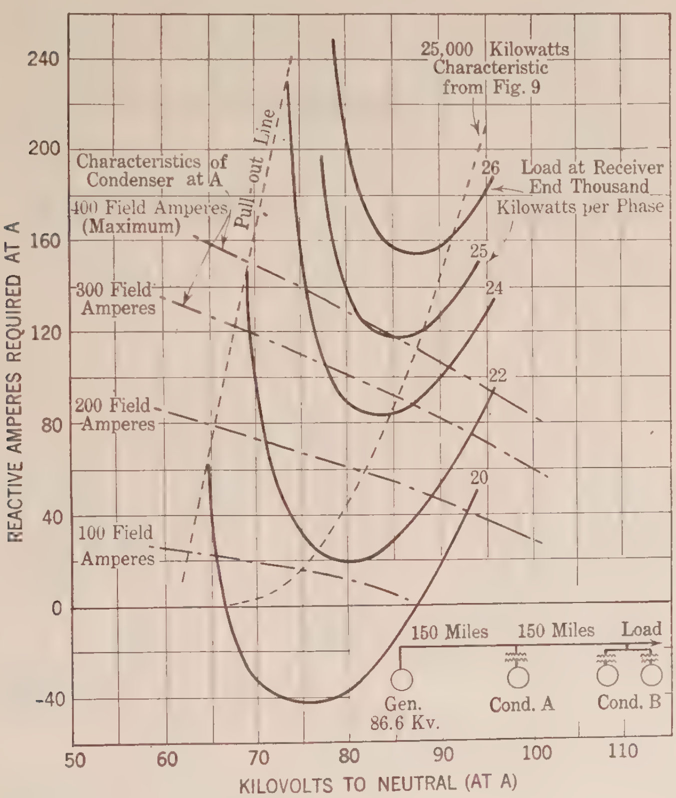

Fig. 12—Relations between Reactive Current and Voltage at the Mid-Point of a 300-Mile Line with Two 25,000 Kv-a. Condensers at the Receiver End

Load 90 per cent power factor

in connection with the field circuit has been indicated is too sluggish to introduce a state of artificial stability extending beyond that produced by constant excitation even on steady loads.

The effects of fluctuating loads and load surges have not been considered. A load change of the type of a short circuit may be studied on the assumption that the field current of the condensers does not change during the period of load adjustment, but for fluctuating loads it will be practically impossible to determine the rate of increase of excitation with respect to the rate of increase of load.

DIRECTIVE RADIO FOR NAVIGATION

The Bureau of Standards in cooperation with the Signal Corps and the Air Service of the Army is developing an improved type of radio beacon, which it is believed will do much to increase the safety of navigation both on the water and in the air.

Briefly the device consists of an ordinary form of radio transmitting set located at a light house or other suitable point and connected to a pair of coil antennas. Each antenna consists of a single turn of wire in the form of a vertical rectangle about 100 ft. long by 50 ft. wide. These two rectangular antennas cross each other at an angle of 135 degrees. Signals are transmitted alternately from each of these coils and since this type of antenna transmits a maximum signal in one direction and practically no signal at right angles, a receiving set located along the line bisecting the angles formed by the two crossed coil antennas will receive signals of equal intensity from each of the coils.

A ship or airplane provided with an ordinary receiving set may thus be guided along this bisecting line toward or away from the radio beacon. Should the vessel deviate either way from this course, the two alternate signals will become noticeably unequal in intensity. The proper course may thus be followed regardless of visibility conditions and without dependence on land marks or the magnetic compass.

APPROVED ELECTRICAL MINE EQUIPMENT

The classes of electrical equipment that have been approved by the Department of the Interior, through the Bureau of Mines, for use in mines, are steadily growing and the number of each type are as follows: Electric cap lamps, 5; electric hand lamp, 1; a-c. and d-c. shortwall coal-cutting machines, 20; portable electric drills, 4; single-shot firing devices, 2; storage-battery locomotives, 5. These are all described in Technical Paper 333.

There is a field for other lines of safe equipment for various services such as pumps, room hoists, arcwall coal-cutting machines, air compressors, coal-loading machines and storage-battery operated coal-cutting outfits. Also, there is a need of approved mine telephones and approved switches or junction boxes for use at the end of trailing cables. The Bureau of Mines has schedules covering these various services, and is prepared to investigate the permissible features of any of the foregoing apparatus as soon as it shall have been designed and submitted for inspection, test and approval. The Bureau has no mandatory powers and cannot force any manufacturer to either design or submit safe equipment. The ruling that safe equipment must be used in certain mines can only be issued by the proper State official, except in leased coal mines where the Government, as a lessor, becomes the owner and has reserved certain rights with respect to safety.

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***Review of the Subject.**—Radio broadcasting has drawn attention to the problems involved in obtaining high quality in systems for the electrical transmission and reproduction of sound. This paper gives the general requirements for such systems, discusses briefly the factors to be considered in design and operation and indicates to what extent the desired results can be obtained with the means now available.*

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THE primary function of telephone circuits, as normally used in commercial service, is the electrical transmission and reproduction of speech sounds. In considering the operation of such a system, the reproduced sounds are referred to as having two properties, intelligibility and naturalness. While these two properties are not by any means unrelated and are both of importance in all sound reproducing systems, the first is naturally the more important in a commercial communication system. In broadcasting and public address systems, the communication function is supplemented by the function of entertainment and the property of naturalness, therefore, increases in importance in the reproduced speech. Furthermore, the use of music with such systems imposes, in general, more severe requirements upon them because of the wide range of frequencies and intensities required for proper appreciation.

In this paper the fundamental requirements for a system for faithfully transmitting and reproducing sound are outlined, and their applications considered, particularly in connection with broadcasting and the use of loud speakers.

In any system for the electrical transmission and reproduction of sound there are three essential elements: A means for converting sound into electrical energy, usually called the telephone transmitter or microphone; a means for converting electrical energy into sound, usually called the telephone receiver; and means for transmitting the electrical energy from the transmitter to the receiver.

In the operation of such a system, there are three general requirements which it is desirable that the reproduced sounds should meet: First, that they be at about the same loudness as people are accustomed to hearing the original sounds; second, that they be free from appreciable distortion, that is, that the character of the reproduced sounds be so close to that of the original sounds that the ear cannot distinguish between them; and third, that they be free from extraneous sounds. The degree to which these requirements of loudness, freedom from distortion and noise are met is the measure of the quality of the system.

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The discussion in this paper will be directed primarily to the second of the above requirements, that is, the matter of obtaining accurate transmission and reproduction of the original sounds, and the requirements of loudness and noise will be considered only in so far as they have a bearing on the principal discussion. In this connection, it may be noted, that with the development of practically distortionless amplifiers, it is possible to compensate for the losses in volume incurred in transmission and in the conversions between sound and electrical energy, and thus obtain any degree of loudness desired. The problems of eliminating noise, however, are in many cases difficult, but are too extensive to be within the scope of this paper.

DISTORTION

The sounds which comprise speech and music involve, as is well known, complicated pressure variations. For any small interval, of time, these pressure variations may be resolved into a series of component sinusoidal waves. As the speech or music proceeds, however, the amplitude, the frequency and the phase of these components change. The transmission and reproduction of such sounds may be conveniently considered as a matter of transmitting and reproducing the several component waves.

For a system to be ideal from a quality standpoint, these components must be reproduced unchanged, and no new components introduced. Experience has shown that changes in phase such as are usually obtained, produce no effects which are noticeable by the ear. Also, as discussed later, all the amplitudes may be diminished or increased uniformly through an appreciable range before the quality is affected.

The requirements then for no noticeable distortion in a sound-reproducing system may be stated as follows:

1. The reproduced sounds shall have the relative intensities of the component frequencies the same as the original sound.

2. The reproduced sounds shall not contain any components of frequencies not present in the original sound.

Failure to meet the requirement set up in (1) is referred to as "frequency distortion." This results

when a system has different transmission efficiencies for the different frequencies.

Failure to meet the requirement set up in (2) is referred to as "non-linear distortion." This results when the relation between the output and input powers is not independent of the magnitude of the input power. Distortion of this type may be obtained from the iron cores of transformers or other coils, from vacuum tubes, from carbon transmitters and from diaphragms or other vibrating mechanical parts. All of these have a load characteristic which generally has a practically linear relation between output and input when operated below certain energy limits, but which shows a non-linear relation between output and input when the input power exceeds these limits. Operation over the non-linear part of such a characteristic results, in addition to changing the intensity relations of the components of the original sounds, in the setting up of components of frequencies which may be different from those of the components in the impressed wave.

Another important factor in the reproduction of sounds which is not generally appreciated is that apparent distortion is obtained if the loudness of the reproduced sounds is materially outside of the range in which the listeners are accustomed to hearing the original sounds. Recent work[1] in hearing has shown that the transmission mechanism of the ear is non-linear in its response even at loudness levels commonly used in speech and music. From this it is seen that the interpretation of complex sounds by the ear is partly accomplished by the "subjective" frequencies introduced by the ear itself. Due to this non-linear characteristic of the ear, when the intensities of reproduced sounds are materially different from those of the original sounds, there is an apparent distortion.

With these requirements in mind, consideration will now be given to the extent to which they can be met with the means and methods now available. In this connection, three electrical transmitting and reproducing systems will be discussed, a high quality telephone circuit, the public address system and the broadcasting system. The first two and the elements used in them have been previously described in some detail. A brief description of them will be given here, however, to show their similarity with the third, which will be discussed more comprehensively, and also to indicate to some extent the evolution of high quality reproducing means. It will be noted that the successful design, maintenance and operation of any high quality system depends upon the development of methods of measuring its operational characteristics, such as the relation between input and output energies over a range of frequencies and intensities.

1. Physical Measurements of Audition and Their Bearing on the Theory of Hearing, H. Fletcher, *Jour.* Franklin Ints., September, 1923.

High Quality Telephone Reference System

A number of years ago a telephone circuit was set up in the Bell System Laboratories in which use was made of the various available means to eliminate distortion as much as possible. This was used as a reference circuit in a comprehensive investigation of the effects on the intelligibility of reproduced speech sounds, of variations in the volume of the reproduced sounds, of various types and amounts of distortion and of various amounts and kinds of extraneous noise.[2] This system and the variation of its efficiency with frequency are shown in Figs. 1 and 2.[3] It has also negligible noise and non-linear distortion for the sound powers that it is designed to handle, that is, those corresponding to talking in the normal way over a telephone circuit.

With this system, the fundamental vowel and consonant sounds used in speech are reproduced so well that when a series of such sounds are impressed upon

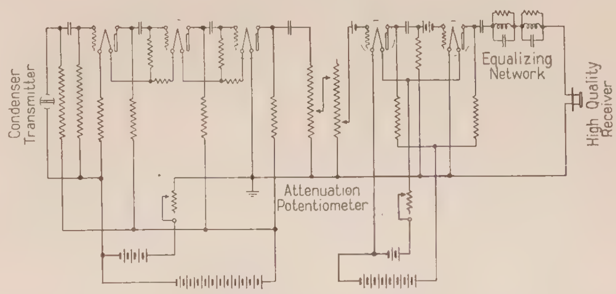

Fig. 1—Circuit of High Quality Telephone Reference System

the system 99 per cent, are correctly understood. This recognition is for the condition when these sounds are combined into meaningless monosyllables, which makes the test much more severe than for these sounds as ordinarily used in conversation where the context aids in the recognition. The degree of recognition obtained with this system is within a few tenths per cent, as good as that obtained by direct hearing. This circuit, therefore, from the standpoint of intelligibility of speech is practically perfect.

This high quality circuit made use of several important developments. First is the condenser transmitter which gives a practically distortionless conversion from sound to electrical energy. This transmitter, which has been previously described,[4] uses a thin metal diaphragm, tightly stretched and placed close to a heavy metal plate. The diaphragm and the heavy plate form an electric condenser and the air film

2. The Nature of Speech and its Interpretation, H. Fletcher, *Journ.* Franklin Inst., June, 1922.

3. The "transmission units" used in Fig. 2 and elsewhere in this paper are a logarithmic function of power ratio. The number of transmission units, N, corresponding to the ratio of two amounts of power P_1 and P_2 ,is given by the relation $N = 10 \log_{10} P_1/P_2$. The power ratio corresponding to N units is therefore $10^{N(.1)}$.

4. Wente, *Phys. Rev.*, June 1917 and May 1922. Crandall, *Phys. Rev.*, June 1918.

between the two serves to damp the vibration of the diaphragm.

Second is the design of vacuum tube amplifiers which are distortionless over a wide range of frequencies and loads. The design of such amplifiers will be discussed in a future paper, so will not be described here, other than to show later some amplifier frequency characteristics which have been obtained.

Third is a telephone receiver having small distortion. For this a permanent magnet type of receiver was used in which the principle of damping the diaphragm by an air film was employed in a manner similar tothat described above for the condenser transmitter.

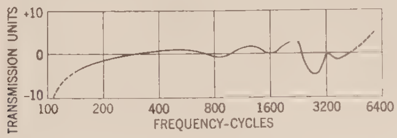

Fig. 2—Frequency Response Characteristic of High Quality Telephone Reference System

Fourth is the use of a network of impedances designed to introduce into the circuit the distortion which compensated for any distortion in the system which it was not practicable to eliminate in the several parts. In this circuit this compensation was needed primarily to take care of residual distortion in the receiver.

Public Address System

The public address system and its applications were described in two papers presented before this Institute in February, 1923,[5] and as already noted will be referred to only briefly here. In the public address system which was used at the presidential inauguration in March 1921, the condenser transmitter and high quality amplifiers were used to obtain good quality. In November, 1921, this public address system was used with the toll lines to transmit the Armistice Day Service at Arlington, Va. to New York and to San Francisco. At this time use was made of a new design of high quality transmitter, the double carbon button transmitter employing the stretched damped diaphragm of the condenser type. At this time also corrective distortion networks were employed to compensate for the distortion of the non-loaded cable circuits which were used to connect to the toll lines. The "volume indicator" for showing the power carried by the amplifiers was also used on this occasion in order to keep them from being overloaded and causing non-linear distortion. This volume indicator, as described in the papers referred to, consists of a vacuum tube amplifier-rectifier operating a quick acting ammeter. In both these loud speaker applications, extensive use was made of single-frequency measuring apparatus for determining the efficiency of the various parts of the system over a wide range of frequencies.

5. Public Address Systems, Green and Maxfield, Journal of A. I. E. E., April, 1923.

Use of Public Address Systems with Telephone Lines, Martin and Clark, Journal of A. I. E. E., April, 1923.

Broadcasting System

When radio broadcasting started its phenomenal development, this high quality apparatus and the associated testing methods found new applications. It will be noted that the public address and the broadcasting systems are very similar, the main difference being the use of radio in the latter as a convenient means of reaching a large number of receiving stations from one transmitting station.

In Fig. 3 are indicated the essential elements of a radio broadcasting system. In this system, M is the microphone or means for converting from sound to electrical energy, A_1 is the amplifier used to increase the output of the microphone before transmitting it over the wire connection L_1 to the broadcasting station. The amplifier A_2 and the radio transmitter $R\,T$ increase and transform the energy into that which is put upon the antenna. At each of the receiving stations, there are required, in general, a radio receiver $R\,R$ for converting the received radio frequency currents into audio frequency currents, an amplifier, and a telephone receiver, either of the type held to the ear or of the loud speaker type.

In regard to the wire line L_1 to the broadcasting station, it should be noted that while much of the material to be broadcast is at present specially produced in a studio closely associated with the broadcasting station, a large and probably increasing proportion of the broadcasting material is produced at points at some distance from the station. In this latter class come (1) material which is not given primarily for broadcasting, such as concerts and speeches for some local audience, (2) material given in a studio located at a point convenient to the artists or speakers, but remote from the broadcasting station and (3) announcements of the progress of athletic games or other sporting events which are made from the place where the games are held.

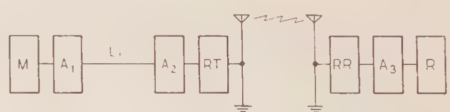

Fig. 3—Schematic Diagram of Radio Broadcasting System

Broadcasting Material

The material used for broadcasting consists in general of speech or music. Speech sounds are extremely complex in their nature and involve frequencies from about one hundred cycles to above six thousand. The first two charts in Fig. 4 show the sound spectra for the sung vowels "ah" and "ā". When these and the other vowels are spoken they are modulated both in pitch and volume from this steady state, the particular manner of starting or stopping them determin-

ing the so-called stop consonants[6]. The unvoiced fricative consonants, "s", "f" and "th", have their sound spectra in the upper frequency regions between 4000 and 10,000. In general most of the energy is carried by the vowel sounds and at frequencies below 1000 cycles, but the fine modulations of the vowels which produce the stop consonants and also the production of the fricative consonants involve frequencies mostly above 1000 cycles. For this reason it is well to bear in mind that the importance of any frequency region for carrying the energy in speech is quite different from that for carrying the intelligibility. On Fig. 5 are shown two curves which contrast this difference.[7] The curve for intelligibility does not directly take into account the naturalness of the sounds. It is found, for example, that while a system, which transmits only the frequency range from 500 to 2000 cycles, reproduces speech which can be easily understood, it leaves much

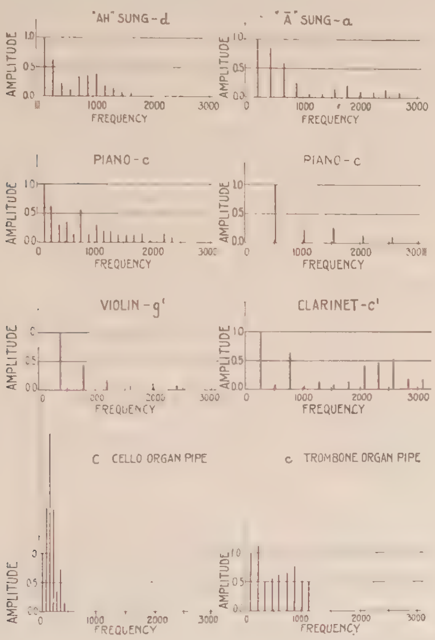

Fig. 4—Sound Spectra of Typical Musical Tones

to be desired from the standpoint of naturalness. In broadcasting, a broader frequency range is desirable because of the importance of naturalness. Results can be obtained for speech which are good for intelligibility and fairly good for naturalness with a frequency range from about 100 to 3000 cycles, although appreciable improvement is obtained by the extension of the upper end of the range.

The various types of vocal and instrumental music, solo, choral and orchestral, have widely varying characteristics, with fundamental tones as low as 16 cycles and harmonics above 10,000 cycles. The breadth of this range makes its proper handling in a reproducing system extremely difficult, particularly when the large energy of some of the low notes such as used in the pipe organ are taken into account. Fig. 4 gives also charts showing the sound spectra for some typical musical instruments when they are sounded at the pitches indicated. It is very difficult to obtain any quantitative measurements of the importance of the various frequency regions for properly transmitting music, but it has been found that with a frequency range of from about 50 to 5000 cycles good reproduction can be given for most kinds of music. In this connection it may be pointed out that the pitch of musical tones of very low pitch is carried to the ear mainly by the harmonics rather than by the fundamental.[8] For example, with a system not reproducing any frequencies below 100 cycles, the pitch is preserved for notes even as low as 30 cycles. The musical quality is marred, however, when the lower frequencies are not present.

Another important characteristic of speech and music is the intensity range. For speech the range of the average power is of the order of 1000 to 1. In music, such as that given by a symphony orchestra, the corresponding range may be as great as 100,000 to 1. These ranges have an important bearing on the load capacity required for the parts of the broadcasting system as will be brought out later.

Pick-Up of Material

In picking up material for broadcasting, that is, in getting the sound energy into electrical energy, the general requirement would seem to be to get to the high quality microphone the sounds in the form in which a skilled listener would wish to hear them if he were free to choose his location with respect to the source of these sounds. In this respect, the skilled listener would be largely governed by hearing the sounds under the accustomed conditions with all undesirable noises, echoes and abnormal reverberations removed. In considering the pick-up of material for broadcasting it should be noted, however, that it corresponds to listening with one ear, that is, the binaural sense of direction which is normally obtained in hearing the sounds directly, is lacking. With binaural audition, it is possible to concentrate on one sound source and to disregard somewhat the effect of other sounds coming from diferent directions or distances. Because of the monaural character of broadcasting it is necessary, therefore, to go even further in reducing noises and reverberation at the transmitter than would be the case for an observer using two ears at the same location.

In picking up sounds, undesirable effects which may be classed as distortion, may be obtained by having either too much or too little reverberation or, where the sounds come from several sources, such as in the case of a quartet or an orchestra, by not having the proper

6. The Nature of Speech and its Interpretation, H. Fletcher, *Jour.* Franklin Inst., June 1922.

7. Curve for energy distribution given in Analysis of the Energy Distribution of Speech, Crandall and MacKenzie, *Phys. Rev.*, XIX, No. 3. Curve for Intelligibility derived from data given in paper mentioned in Note 6.

8. Physical Criteria for Determining the Pitch of a Musical Tone, H. Fletcher, *Physical Review*, September 1923.

relation between the intensities of the sounds which reach the transmitter from the several sources. Since most speeches and musical selections are given indoors, a certain amount of reverberation is generally present. Because of this customary condition, music particularly, without reverberation, such as is obtained in a heavily padded room, sounds "dead." Too much reverberation, on the other hand, causes one tone to drag over into a succeeding one and tends to blur the sounds. In some tests carried out by Prof. W. C. Sabine with rooms in which the reverberation was varied it was found that a group of musicians consistently selected a particular reverberation condition as being most desirable for the piano.[9]

Much of the material that is broadcast is given in a special studio where it is possible to control the conditions. The studio can be placed in a quiet location, it can be treated with absorbing material to give the proper amount of reverberation and the speaker, singers, or musicians can be placed with respect to the microphone so as to obtain the desired balance between the direct sounds and the reverberation and also between the sounds from the several sources where more than one source is used. With the large number of variables involved, it is not as yet possible, however, to give general rules governing all of them.

In regard to the matter of equipping such a room with sound absorbing material, it is seemingly a common mistake to cover as completely as possible the ceiling, walls and floor of a studio with such material. Such a room in addition to making the music sound "dead," makes it difficult and in some cases impossible for a singer or violinist to keep on the key because they are accustomed to get the pitch of one note from the reverberation of the preceding note. In one studio of about 20 by 30 feet, in which a large amount of experimental work was done to get a suitable reverberation for music, the final arrangement is a hardwood floor with a few rugs, the walls hung with monks cloth and about two-thirds of the ceiling covered with one inch hair felt. The reverberation can be increased when desired by taking up rugs or pulling back some of the wall hangings. In such a room for speaking, however, undesirable reverberation is obtained if the speaker is more than about four feet from the microphone. In connection with the statement regarding the effect of the monaural character of broadcasting on the requirement for the placing of the microphone, it is of interest to note that the reverberation time for this studio, using Sabine's method and coefficients, was somewhat less than that found to be desirable in his tests which were referred to.

There is an increasing demand in broadcasting for the use of material which is not being given specifically for broadcasting, such as a speech by some well-known person or a concert by a symphony orchestra. In such cases it is not usually possible to change the acoustics, so that the problem becomes one of getting the best location for the microphones.

For a speech, the problem is generally not difficult as the microphone can usually be located within about three feet of the speaker so as not to restrict unduly his usual movements. For a symphony orchestra of 75 to 100 pieces the problem presents some difficulties. It is desirable to get the transmitter far enough away from the orchestra so that the paths from it to all the pieces of the orchestra are about equal, in order to get proper balance between the parts, and at the same time, not to be so far away from the orchestra that the incidental noises of the audience are loud compared to the music. Good results have been obtained under these conditions by suspending the transmitter from the ceiling of the concert hall over a point on the floor about thirty to fifty feet from the orchestra and about ten to twenty feet from the ceiling. This brings it over the audience, but far enough away so that noises from it are not bothersome and far enough away from

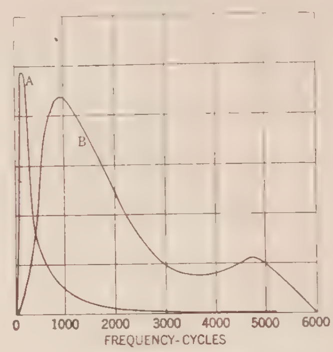

Fig. 5—Frequency Characteristics of Speech
Curve *A*—Energy distribution
Curve *B*—Relative importance for intelligibility

the orchestra to get a good balance between the parts. Also this permits the sound striking the transmitter through reverberation to be sufficiently appreciable as compared to the direct sound. This reverberation gives the impression of the orchestra playing in a concert hall, which, of course, is the natural condition. The scheme of using several transmitters distributed throughout the orchestra, in order to pick up the different parts, is in general undesirable because of the lack of reverberation and the difficulty of getting proper balance between the parts.

Transmitters

Two transmitters or microphones of the air-damped, stretched-diaphragm type have been extensively used for broadcasting, the condenser type and the carbon button type

The frequency response characteristics of present models of these two types of transmitters are shown in Fig. 6, that designated *A* being for the carbon and that designated *B* for the condenser type. Both of these have already been described elsewhere and will not need further consideration here. It should be noted that the condenser type can be designed to have a

9. Collected Papers on Acoustics, Harvard Univ. Press page 75.

frequency characteristic of almost any degree of flatness desired. Material improvements have been made recently on the carbon type. One of these is the use of a light metal diaphragm by means of which the electrical output for a given sound input has been increased about ten times. A second important improvement in the carbon type has been a change in the acoustic spaces associated with diaphragm to reduce the distortion. The advantage of the carbon type of transmitter is that it requires two stages of amplification less than the condenser type and approaches it closely from the standpoint of freedom from distortion. As a result of the small diaphragm motions used in this transmitter the carbon button is worked far below the saturation point.

Transmission to Broadcasting Station

When material is picked up at a point remote from the broadcasting station, care must be used to avoid distortion in getting it to the station. When, as is usually the case, the point where the material is given and the broadcasting station are in the same city, it is generally possible to get non-loaded telephone cable circuits between the two points. By the use of corrective distortion networks or "attenuation equalizers" with such circuits, uniform transmission efficiency

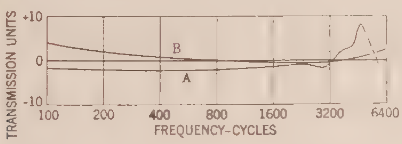

Fig. 6—Frequency Response Characteristics of High Quality Transmitters

Curve *A*—Stretched diaphragm double carbon button transmitter

Curve *B*—Stretched diaphragm condenser transmitter

over the desired frequency range, can be obtained even though the circuits themselves may have considerable distortion.[10] With these equalizers it is possible to equalize such circuits so that the variations of efficiency over the frequency range from the average value are less than one transmission unit.

The high quality transmitters which are used to pick up the material to be broadcast have energy outputs which are so low as to require amplification before they are transmitted to the broadcasting station in order to over-ride extraneous noises which may be encountered. Such amplifiers, in addition to having uniform efficiency for a broad frequency range, must also be capable of giving a large range of amplification and of handling without distortion a wide range of power in order to take account of the variations in the volume of sounds which are impressed upon the transmitter. In picking up speeches, for example, different amplifications may be required for the different loudness of the voices of the speakers. In making a speech, an orator often intentionally changes the loudness of his voice for emphasis. The amplification must be such as to permit low parts to be heard satisfactorily and also the amplifier must be capable of handling the loud parts without overloading. The amplification can be reduced for the loud parts to reduce the power handled, but the power output cannot be kept constant without spoiling entirely the emphasis effects desired by the speaker. In music, the volume of sound varies frequently and over a large range.

Considering this matter from the standpoint of the operator of a radio receiving set, it is desired first, that when the volume of the original sound is at its low point the reproduced sound should be loud enough to over-ride static and other radio frequency interference, incidental noises in his set and room noise at his set. With this condition satisfactorily met, it is desired that the receiving set be capable of handling the maximum volumes of sound without overloading. The sets now available are capable of handling in the order of about a hundredth of this range and to make them handle this larger range would at present be practically prohibitive from a cost standpoint. The same requirement imposed upon the radio transmitter at the broadcasting station would also increase its cost by a large factor. The circuits used between the point where the material is picked up and the broadcasting stations also impose restrictions on this volume range. The lower limit to the power placed upon such circuits is set by the extraneous noise which may exist upon them due to induction from other circuits. The upper limit to the power on the circuit is determined by two factors, one, the capacity of the amplifiers which may be used and the other, the interference which this circuit would cause in other telephone circuits which are in the same cables with it. These circuit requirements, in general, limit the power range which can be satisfactorily handled to a range of about 1000 to 1. From the standpoint of the circuits alone, this range could be increased by special measures which, however, it might not always be practicable to apply.

These conditions, therefore, make it highly desirable to control the volume range given out by the amplifier associated with the transmitter. Some of this control could be exercised at other points in the system, but it is obviously desirable to have it all take place at one point and keep the rest of the system fixed. For this purpose the amplifier associated with the transmitter is equipped with a means for giving a quickly adjustable amplification. To make these adjustments correctly, it is necessary for the operator of the amplifier to know what power is being delivered by it. Use is made here of the "volume indicator," which is bridged across the output of the transmitter amplifier and the amplification of the volume indicator varied by means of a calibrated potentiometer until a standard deflection is obtained. The amplification required to get this deflection is then a measure of the output of the transmitter amplifier. This is supplemented by a monitoring loud-speaking receiver bridged across the circuit at the same point. By the aid of these, the operator

10. Use of Public Address System with Telephone Lines, Martin and Clark. Jour. A. I. E. E., April 1923, page 361.

can check the operation of the transmitter and its associated amplifier and keep the volume of electrical power delivered to the broadcasting station between certain prescribed limits which are far enough apart to give suitable expression to the music or speech. When the sounds striking the transmitter become too loud, the gain of the transmitter amplifier is reduced and when these sounds become too low, the amplification is increased, these changes being made gradually in order to avoid noticeable abrupt shifts in volume. The limits between which the electrical power is kept, are those which have been found experimentally to avoid overloading any part of the broadcasting system and to keep above any extraneous noises in the system.

This adjustment of the gain of the transmitter amplifier to keep the power delivered to the broadcasting set within certain prescribed limits is required also when the pick-up of the broadcasting material is in a studio at the broadcasting station.

Broadcasting Station

In the radio broadcasting transmitter the incoming electrical power is generally amplified before being used to modulate the radio frequency carrier. In this transmitter, the frequency and volume range requirements, discussed for amplifiers, also apply. The amplification obtained in this part of the system should generally be fixed and all necessary adjustments during operation made in the amplifier associated with the microphone. The following discussion of the broadcasting station is from the standpoint of operation, as the apparatus itself has been described in another paper.[11]

Operating Requirements. With a fixed setting of the radio transmitter, it is important to determine the maximum power which can be introduced into it without causing noticeable overloading. To do this, there are required a means for indicating power such as a volume indicator, a high quality radio receiving set, a high quality loud speaker and high quality amplifier for operating it and some skilled observers. With the loud speaker, first determine for speech and several kinds of music, the maximum power which can be delivered by the microphone amplifier before overloading is detected. Then with the amplifier connected to the radio transmitter and with the radio receiving set, high quality amplifier and loud speaker, determine what power input into the radio transmitter causes overloading. If this is less than has been previously determined as the overloading point of the microphone amplifier, the overloading is in the radio transmitter. The station should then be operated so that the power delivered to the radio transmitter never exceeds this amount.

As a check on the operation of the station, a monitoring system such as the following should be used constantly. In this system a loud speaker and associated amplifier are connected either directly to the output of the microphone amplifier or to the output of a high quality radio receiving set. In these two connections the reproduced speech or music should sound the same and neither should show any signs of overloading.

This matter of guarding against overloading has been stressed so much because it is a common source of poor quality in broadcasting. Furthermore, it is often a defect in operation rather than in apparatus and as such, constant care is required to avoid it.

Another important factor in good broadcasting is insuring that the system and all its parts maintain their good quality. For this purpose, periodic tests should be made of the complete system with single-frequency currents over the range to be transmitted. For these tests the microphone can be replaced by a source of known amount of current and a measurement made of the electrical output of the high quality monitoring radio receiver. For such tests, use can be made of a "dummy" antenna, if it is not possible or desirable to go out "on the air."

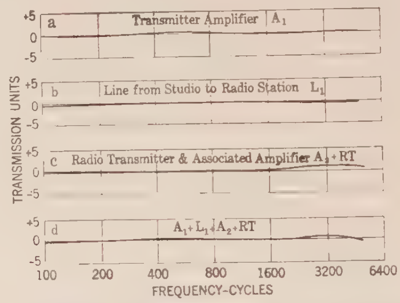

Fig. 7—Frequency Response Characteristics of Radio Broadcasting Station

It is with the use of a testing system such as outlined that it is possible to find out wherein the system falls down and either change the design of various parts of the system or avoid imposing upon the system conditions for which it gives poor quality. By following this method it is possible to get the distortion between the sounds striking the microphone and the energy radiated from the antenna below the amount detectable by the ear.

Frequency Characteristics. The curves of Fig. 7 indicate what can be done in obtaining good quality in broadcasting. These curves are for station WEAF in New York City where the studio and the broadcasting station are in different buildings, the two being connected by a cable circuit about a mile and a half long. Curve *a* is for the microphone amplifier (A_1 in Fig. 3), curve *b* for the equalized line between the studio and station (L_1 in Fig. 3) and curve *c* for the radio transmitter and associated amplifier (*R T* and A_2 in Fig. 3). Curve *d* is for the system from electrical power of audio frequency leaving the microphone to power from the antenna at radio frequencies. The curve for complete operation of the broadcasting system from sound in the studio to radio frequency power in

11. Transmitting Equipment for Radio Telephone Broadcasting, E. L. Nelson. Presented I. R. E. Jan. 16, 1924.

the air can be obtained by combining curve *d* with the microphone curve from Fig. 5. Curve *d* shows the station as it is now operated. The small variations from the horizontal line can, of course, be eliminated, if worth while, by the use of an attenuation equalizer.

Receiving Station

The apparatus at the receiving station of a radio broadcasting system is required to perform three and preferably four functions. The three are selectivity, conversion of electrical energy from radio to audio frequency and conversion from electrical energy to sound. The fourth is amplification. The first two, selectivity and detection, are the essential functions of a radio receiving set. While it is not within the scope or purpose of this paper to discuss in detail various types of radio receiving sets, some general discussion will be given of the functions of the set in so far as they affect quality. Similar consideration will also be given to the other functions of the receiving station apparatus.

Amplification. The function of amplification is desirable and often necessary in order to bring the energy received by the antenna up to a point where it can produce sounds loud enough to be easily heard. This is particularly the case where loud speaking telephones are used to perform the third function. While it is a relatively simple matter to provide amplification without distortion, it is in performing this function that serious distortion is now introduced at many receiving stations, particularly when the amplification is in the audio frequency range or when it is obtained by regeneration. The provision of amplification without distortion is largely a matter of proper design, based on a knowledge of the characteristics of the tubes used and means for coupling stages together. A common offender in audio frequency amplifiers is the transformer, although with proper design it can be made to function satisfactorily.[12]

Selectivity. In performing the function of selecting the radio wave which it is desired to receive and discarding others, there is a conflict between the degree of selectivity, or sharpness of tuning, and width of the frequency band for the reproduced sounds. If this band width for the reproduced sounds is to be 5000 cycles and both side bands of the radio carrier are to be received, obviously all other waves within a band width of 10,000 cycles will also be received. Further, because it is not possible with the resonant type of selective means to let through without distortion this 10,000 cycle band and at the same time cut off absolutely all other waves near the edges of this band, the set will respond to a wider range of frequencies.

There are, generally speaking, two types of selective means used in radio receiving sets, one a circuit containing one or more adjustable resonant elements and the other a circuit having a fixed selective element with adjustable means for converting the received radio waves into waves of frequencies which will pass through the selective element. With the first type of selectivity, which includes the selectivity obtained with regeneration, the distortion of the reproduced sounds is obviously not fixed but will vary with the sharpness of tuning used. With the second type of set, the selectivity is fixed in the design and involves, therefore, a predetermined compromise between distortion of reproduced sounds and degree of selectivity. Fig. 8 illustrates quantitatively what this compromise entails and also the range of distortion which may be obtained with a set of the variable selectivity type. Curve *A* shows the characteristic for one stage of audio frequency amplification in a particular receiving set, which is seen to cause appreciable distortion only at the low frequencies. As the distortion caused by radio tuning affects only the higher audio frequencies, curve *A* corresponds to a set with no radio selectivity. Curves

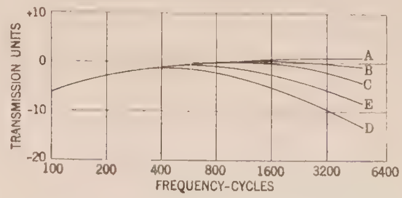

Fig. 8—Variation of Audio Frequency Response Characteristics of Radio Receiving Sets with Different Degrees of Selectivity

Selectivity expressed in terms of attenuation for radio frequency 10,000 cycles from frequency for which set is tuned.

Curve *A*—Attenuation 0 transmission units
Curve *B*— " 10 " "
Curve *C*— " 20 " "
Curve *D*— " 40 " "
Curve *E*—Radio set with fixed selectivity.

B, *C* and *D* indicate the effect of increasing degrees of radio selectivity. These three degrees of selectivity are such that if there is an interfering signal having the same intensity in the ether as the signal being received, but having its carrier frequency 10,000 cycles higher or lower, it will produce an audio signal at the output of the set 10, 20 and 40 transmission units respectively lower than the level of the signal being received. In other words a receiving set having the characteristic *B* which is very desirable from the quality standpoint will be much less selective against interference than one having the higher distortion characteristic *D*. As an example of a practical compromise, curve *E* shows the characteristic of a set of the fixed selectivity type which was designed for general all around use in receiving both local and long distance broadcasting. In this set a frequency 10,000 cycles higher or lower than the frequency to which the set is tuned suffers a loss of 34 transmission units.

The fixed selectivity type of set has some advantage in that its operation is definite and is less likely to give poor quality due to improper operation. The operation of this type of set can be materially improved by employing for the fixed selective element a band pass filter. Such a filter has the advantage that the charac-

12. Telephone Transformers, W. L. Casper, presented A. I. E. E., Feb. 8, 1924.

teristic of the transmitted range can be made practically flat for any desired band width and to present a large attenuation for frequencies outside the band. For example, with a well designed filter of this type, the characteristic of the transmitted audio frequency band can be made practically flat up to 5000 cycles and the discrimination against other signals can be made even greater than that given above for curve D. This type of selectivity employing a band pass filter was used in the receiving sets of the Catalina Island radio telephone system.[13]

Conversion from Radio to Audio Frequency. In converting the electrical energy obtained from the antenna from radio to audio frequency, there is in general no difficulty from the standpoint of distortion provided the "detector" for making this conversion is worked below saturation.

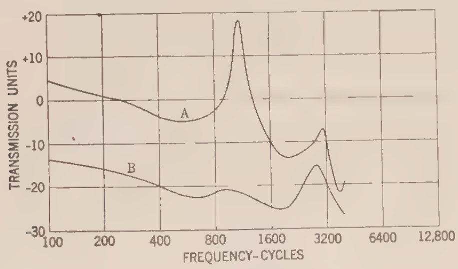

Fig. 9—Frequency Response Characteristics of Telephone Receivers

Curve A—Commercial type
Curve B—Specially damped receiver

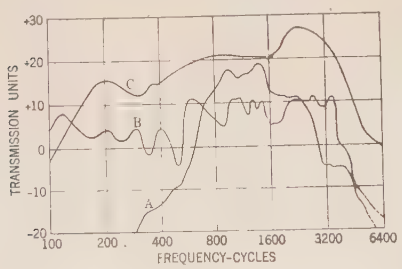

Fig. 10—Frequency Response Characteristic of Loud Speaking Receiver

Curve A—Commercial type
Curves B and C—Experimental models.

Conversion from Electrical Power to Sound. The conversion from electrical power to sound may be accomplished either by the head type telephone receiver or by a loud-speaking telephone, the latter being obviously more desirable for this purpose.

In Fig. 9 is shown the frequency response characteristic of a good type of commercial head receiver when held to ear in the usual manner. It will be noted that this introduces appreciable distortion. A material reduction in this distortion can be obtained with the type of damped receiver used in the high quality telephone system described in the first part of the paper. The characteristic of such a damped receiver is shown also in Fig. 9.

In Fig. 10, Curve A gives the frequency response curve for one of the best types of commercial loud speaker. This also introduces considerable distortion, being particularly weak at the lower end of the frequency range. This deficiency while not so serious for speech, is easily noticeable for music. In this figure are given also two curves showing the response characteristic of laboratory models of loud speakers. These are of interest since the means for converting from electrical power to sound are the most serious source of distortion in a system for transmitting and reproducing sounds, and the reproduction given by these models (which will be demonstrated at the time of presenting this paper) is markedly superior to that obtained with the commercially available apparatus, and indicates the future possibilities of broadcasting.

Conclusion

From this consideration of systems for the electrical transmission and reproduction of sound, it has been shown that it is practicable to get almost perfect electrical transmission over a broad band of frequencies from the terminals of the pick-up transmitter to the radio transmitter and from there out into the air. With the condenser transmitter and proper associated amplifiers the conversion from sound striking the diaphragm to electrical energy can also be made without appreciable distortion. With a properly designed and operated broadcasting station, therefore, high quality material can be delivered to the receiving stations.

At present the commercial radio receiving sets and the means for converting from electrical energy to sound now generally available can not fully utilize this high quality material. These receiving and reproducing means can, however, be materially improved. The problem now is to make such improvements available in such a form that their cost will not make their use prohibitive. As yet the commercial production of apparatus incorporating such improvements is in the future.

In view of the distortion which exists at the present receiving stations, the question may arise as to the justification for going as far as has been indicated in the other part of the system. The fact is that with the reproducing means now available, material deviations from the frequency characteristics which have been given for the other parts of the system are detectable and the effect of non-linear distortion readily noticed. In a broadcasting system where one element is used for converting from sound to electrical energy and for distributing this energy to a large number of elements for reconverting it into sound, the expense of getting good results in this one element is not prohibitive and, taking into account the whole system, relatively small.

In broadcasting, the novelty of the system was undoubtedly a large factor in its rapid growth and development. Those who make use of the system are, however, becoming more critical of the service which it renders and the quality of reproduction will be of increasing importance in the future.

13. The Avalon-Los Angeles Radio Toll Circuit, Clement, Ryan and Martin, *Jour.* I. R. E., December, 1921.

Methods for Testing Current Transformers

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Review of the Subject.—*In the sale of electric power especially in large amounts at high voltages, current transformers are universally used to operate the meters from the readings of which the bills are made out. While the secondary currents of such transformers reproduce fairly faithfully on a smaller scale the conditions of current strength and phase existing in their primary circuits, meter engineers are realizing more and more the importance of checking up the accuracy of this link in the chain of measurements.*

Many possible methods have been suggested for testing the accuracy of current transformers. Some are delightfully simple and inaccurate while others involve relatively intricate connections and sensitive apparatus, but give correspondingly more exact results. The present paper gives a critical discussion of the various possible methods with data as to the advantages and disadvantages of each, in order to serve as a guide to the meter engineer in selecting the method best suited to the particular working conditions of accuracy, speed, volume of testing, and intelligence of labor, existing in his plant. In all eleven distinct methods are described, and supplementary suggestions are made concerning various types of detecting instruments, etc.

Introduction

As a result of the continued growth of electric power systems, and the improvement in accuracy of metering methods which has accompanied it, more and more attention is being given both by utility companies and public service commissions to the testing of the instrument transformers which are almost invariably involved in the measurements on which large amounts of electric energy are bought or sold. The choice of which testing method to adopt in any given case depends very greatly upon a variety of conditions, such as the volume of testing work to be done, the accuracy required, the skill of the staff available for making the measurements, and the working conditions such as steadiness of the supply voltage, freedom from stray magnetic fields, etc.

It is the purpose of the present paper to assist the meter engineer in choosing a testing method by assembling in convenient form brief descriptions of the various methods which are now available for testing current transformers, and indicating the advantages and disadvantages of each method.

There will be given first a brief classification of the available methods, together with a discussion of the more important properties of the electrodynamic type of instrument used in many of the testing methods. This will be followed by a brief description of each method with an indication of its advantages and disadvantages, and its probable accuracy, and later by a more detailed discussion of the various forms of detecting instruments which may be used with many of the methods. In Appendix A is given a bibliography which, though by no means complete, lists the more important methods for testing current transformers. The numbers in parenthesis scattered through the text refer to the articles in the bibliography where the particular subject referred to will be found discussed in more detail.

General Considerations

A typical vector diagram for a current transformer is shown in Fig. 1. If the primary current I_1 is divided by the nominal ratio of the transformer, and reversed in direction, we obtain the vector I', which is here represented as being slightly larger than the secondary current I_2 and as lagging behind it by a small angle β. The ratio of the effective values of I_1 to I_2 is defined as the current ratio of the transformer, while the ratio of the effective values of I' to I_2 is defined as the ratio factor and is the quantity by which the nominal ratio of the transformer must be multiplied in order to obtain the true current ratio. The phase angle of the transformer is defined as the angle by which the secondary current leads the reversed primary current. In order to determine the performance of a current transformer completely as part of a measuring equipment, it is necessary to know the values of ratio and of phase angle for all the conditions of use. Unfortunately these two values depend to a considerable extent upon the frequency, the secondary burden, and the value of

FIG. 1

the currents flowing in the transformer windings, and it is therefore necessary to duplicate all of these conditions when the transformer is tested. Since all testing methods require the insertion of some additional apparatus into the secondary circuit, it becomes a matter of very considerable importance in accurate work to insure that proper allowance for this has been made and that the transformer is tested with a burden closely equivalent to that on which it is used in service. It is convenient to determine the ratio and phase angle at secondary current values of 0.5, 1, 2, 3, 4 and 5 amperes since interpolation between these points is satisfactory for determining intermediate values. It is found that well-made transformers having several primary windings which may be connected in series or parallel have substantially the same ratio factor and phase angle with all connections. In transformers of the hole type in which the primary is inserted by the user of the transformer, this constancy of ratio and

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phase angle is not as perfect as in the preceding case, but the variation in these quantities seldom exceeds 0.3 per cent in ratio and five minutes in phase angle.

In the use of a current transformer for the measurement of current, phase angle is, of course, of no importance and it is necessary to measure only the ratio of the transformer. On the other hand, when the transformer is used with a wattmeter or watthour meter on circuits of power factor other than unity, the effect of the phase angle becomes of importance. The effect of this angle has been worked out by Robinson (28) and others (10, 21, 24, 26), and can be expressed by the equation

$$P = \frac{P' R \cos(\theta + \beta)}{\cos \theta} = P' [R(\cos\beta - \tan\theta \sin\beta)] \quad (1)$$

where P = true power in primary circuit
P' = apparent power as observed in the secondary circuit
$\cos\theta$ = apparent power factor as observed in the secondary circuit
R = ratio of current transformer
β = phase angle of current transformer

In some cases where it is known that the transformer will be used on circuits having a particular power factor, it is desirable to make the test in such a manner as to determine not the ratio and phase angle separately, but the particular combination of these two quantities which is included in the brackets in the right hand member of equation (**1**.) This type of test gives the over-all correction factor which must be applied to power or energy measurements at the particular circuit power factor. Any of the methods described below which use electro-dynamic instruments or watthour meters in the measurement, permit of this type of test.

Methods for testing instrument transformers may be classified (6) into (*A*) absolute and (*B*) relative methods as shown in Table I. In the absolute methods the

TABLE I

A Absolute
- *a* Deflection
  - Two Ammeter Method
  - Two Wattmeter Method
- *b* Balanced
  - Mutual Inductance Method
  - Resistance Method
  - Baker Test Ring Method

B Relative
- *a* Deflection
  - Interchanged Ammeter Method
  - Interchanged Wattmeter Method
  - Interchanged Watthour Meter Method
- *b* Balanced
  - Differential Wattmeter Method
  - Bridge Circuit Method
  - Null Bridge Method

ratio and phase angle of a single transformer are determined directly from the observations, while in the latter the constants of the transformer under test are compared with those of a standard transformer of the same nominal ratio which has been previously tested by an absolute method. The absolute methods are suitable for two classes of work (*1*) in standardizing laboratories when the highest accuracy is needed in testing transformers which are to be used as standards and (*2*) in relatively crude measurements under emergency conditions when the standard transformers needed for the relative methods are not available. As is usually the case with any type of measurements, the relative methods are in general simpler and require less sensitive and delicate apparatus for the same accuracy than do the absolute methods, and are therefore to be preferred in most cases.

The methods of either type may be further classified as (a) deflection or (b) balanced methods. In the former the magnitude and phase (or their equivalents) of both the primary and secondary currents are observed separately and the ratio and phase angle computed from these observations. In the latter the effects of the two currents to be compared are opposed and only their vector difference is measured. In the true null methods this difference is completely balanced against a known vector, while in other balance methods of what may be called the "semi-null" type the vector difference is obtained from the deflections of suitable instruments. As in other types of measurement the

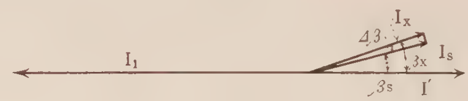

FIG. 2

balance methods have decidedly greater accuracy than the deflection methods and the semi-null methods are usually slightly quicker to operate than the null methods.

Fig. 2 shows a vector diagram applicable to any relative method of testing. The primary current I_1 passes through the primary coils of both transformers and produces currents I_s and I_x in the secondary coils of the standard and test transformers respectively. The differential current ΔI or some effect proportional to it can be measured in terms of I_s. The observations then give the ratio I_s to I_x and the phase difference $\Delta\beta$ between these vectors. The true ratio $\frac{I_1}{I_x}$ is found by multiplying I_s/I_x by R_s (the ratio, I_1/I_s, of the standard transformer). The true phase angle $\beta_x = \Delta\beta + \beta_s$.

In order to avoid repetition later it may be well at this point to review briefly the principal properties of two-circuit electrodynamic instruments (indicating wattmeters and electrodynamometers) since these are often used in transformer testing. Instruments of this type are used for two main purposes (1) as a guide in setting the proper phase relation between the currents in two different circuits, and (2) to measure currents or

differences of currents, such as ΔI of Fig. 2. The fundamental equation for the deflection of an instrument of this type is

$$I_f I_m \cos \theta = k D \quad (2)$$

where I_f is the current in the fixed coil, I_m is the current in the moving coil, θ is the phase displacement between these two currents, D is the deflection and k is a constant of the instrument. As the phase of one of the currents, say I_m, is rotated with respect to that of the other current, the deflection of the wattmeter will rise from zero to a maximum value and then decrease through zero to a negative maximum and then return to its original value. An indication of zero on the instrument corresponds to the value of $\cos \theta = 0$ in equation (2) and hence to $\theta = 90$ deg. It may be noted that the accuracy of locating the zero position is much greater than that of locating the maximum, and therefore the former method should always be used where possible as a means of setting phase. If full-scale deflection of the instrument corresponds to 150 divisions, then an error of one division at the zero mark corresponds to an error in the phase relation between the currents of only 0.4 deg. while the same error at the maximum position corresponds to 6.5 deg.

When used for the purpose of current measurement, one coil is excited by sending through it a current of known magnitude and phase, while the current to be measured is sent through the other coil. The instrument then becomes in effect an ammeter and serves to measure the component of the current in the second coil which is in phase with that in the first. When the fixed coil is excited and the current to be measured is sent through the moving coil, we have the equation

$$I_m \cos \theta = \frac{k D}{I_f} \quad (3)$$

If an ordinary wattmeter, the scale of which is graduated in watts, is used with a separate exciting current I_f in the fixed coil, the value of the constant k is given by $k = w/R_v$ where R_v is the resistance in ohms of the voltage circuit and w is the watts per division. If, on the other hand, the voltage circuit is excited with an auxiliary voltage V, the component of fixed coil current in phase with this voltage is given by

$$I_f \cos \theta = \frac{w\ D}{V} \quad (4)$$

In order to determine completely any current such as I_f or ΔI of Fig. 2, two readings are necessary in which the wattmeter is excited from two sources of current of different phase. After such readings have been obtained it is possible by graphical construction or by trigonometry to determine both the magnitude of the unknown current and its phase relation to either of the auxiliary current sources. From two pairs of such measurements of I_1 and I_2 or of ΔI and I_2, the vector relation of I_1 to I_2 can be obtained in terms of these readings, and gives the desired constants of the transformer. The mathematical treatment of the relations involved is given in Appendix B. The resulting equations are rather complicated and burdensome in the general case, but fortunately they reduce to very simple forms when one of the auxiliary currents is in phase with the secondary current of the transformer under test and the other auxiliary current is in quadrature therewith. It is therefore advisable wherever possible to insert some form of phase shifting device in the circuits supplying the auxiliary current in order that one of them may be brought into phase with the secondary current of the transformer. The use of the general equations of Appendix B should be limited to exigencies when such a phase-shifting arrangement is not available.

In cases which frequently arise in practise where the auxiliary circuits exciting the dynamometer are obtained from a three-phase system, the angle φ in Appendix B becomes 60 deg., and the solution reduces to equations

$$R = \frac{A_1}{A_2 \cos \beta} \text{ or } (1 + A/A_2) \frac{1}{\cos \beta} \quad (5)$$

$$\tan \beta = \frac{2\,(B_1 - N\,B_2) - 1.732\,(A_1 - N\,A_2)}{A_1} \quad (6)$$

$$= \frac{2\,B_\Delta - 1.732\,A_\Delta}{A_2 + A_\Delta} \quad (6)$$

The symbols used in this and the following equations are defined in Appendix B. It will be seen that these are fairly simple if one of the currents can be brought into phase with the transformer secondary current, and the need for a two-phase source of current can be avoided by using these equations instead.

Equation (**3A**) of Appendix B is

$$R\,(\cos \beta - \tan \theta \sin \beta) = A_1/A_2 \quad (\mathbf{3A})$$

It will also be noticed that the left hand member of this is identical with the factor given by equation (**1**) above for the correction to the wattmeter or watthour meter operating at a circuit power factor $\cos \theta$. Consequently any of the wattmeter methods may be used with the auxiliary voltage, making an angle θ with the transformer currents to determine the over-all correction factor for that particular power factor.

It appears from the preceding paragraph that all of the testing methods which involve wattmeters or watthour meters in the measurement have the following advantages and disadvantages in common:

Advantages:

(1) They automatically check the polarity marking.

(2) They permit of test giving combined effect of ratio and phase angle at any specified power factor.

(3) The instruments used are of simple and generally available types except when high sensitivity is desired.

Disadvantages:

(1) They require an auxiliary source of voltage.

(2) If phase angles are to be measured this must be a polyphase source preferably two-phase.

(3) It is highly desirable to provide for shifting the relative phase of the auxiliary voltages.

Absolute Methods

The term "absolute" may be applied to those methods in which the constants of a single transformer can be determined directly without reference to any standard transformer of the same nominal ratio.

Two-Ammeter Method. (6, 17, 24, 28) By far the simplest possible absolute method is the use of two ammeters, one to measure the primary current and the other to measure the secondary current. The ratio of the transformer is given directly by the ratio of the ammeter readings. Of course the phase angle cannot be determined by this method. The accuracy is limited by the calibration errors of the two instruments and by the accuracy with which they can be read simultaneously. With carefully calibrated instruments it is possible to obtain an accuracy of ½ per cent at full rated current, but because of the non-uniform scales of all a-c. ammeters the accuracy falls off to a very poor value at lower currents. This source of inaccuracy can be reduced only slightly by changing the range of the ammeter used in the primary circuit. This expedient is not feasible in the case of the secondary ammeter since the burden imposed on the transformer by inserting in its secondary circuit the coils of an ammeter of lower range than 5 amperes is excessive, so that the results obtained when such lower range ammeters are used are decidedly different from the performance of the transformer when in actual service. Other objections to this method are that its range is limited by the available range of self-contained a-c. ammeters which is about 500 amperes, the method gives no check on the polarity marking of the transformer, and the results give only the ratio of the transformer and not its phase angle.

Two-Wattmeter Method. (6, 17, 23, 24) In this method the current coils of two wattmeters of appropriate range are connected in series with the primary and secondary circuits of the transformer respectively, and the voltage circuits of the wattmeters are connected in parallel with one another and to one or the other phase of an auxiliary source of voltage. If the auxiliary voltage is in phase with the secondary current, the ratio of the watt readings gives the ratio of the transformer. If the phase of the auxiliary voltage is approximately in quadrature with the primary current, the phase angle of the transformer is given by

$$\tan \beta = \frac{B_1 - N B_2}{A_1} = \frac{W_1 - N W_2}{E I_2} \qquad (7)$$

where W_1 and W_2 are the readings of the primary and secondary wattmeters respectively. I_2 is the secondary current, E the effective value of the auxiliary voltage, and N the nominal transformer ratio (see Appendix B).

This method is also simple and quick, and after a set up has once been checked out, it serves to check the polarity of other transformers which may be tested with it. Furthermore, by exciting the voltage circuits of the wattmeters from an auxiliary voltage which is displaced in phase by an angle θ from the transformer currents, the resultant readings give directly the combined error due to ratio and phase angle when used on a circuit of power factor cos θ. As in the preceding method the range is limited by the range of available wattmeters which is about 200 amperes. The accuracy may be as high as 0.2 per cent at full current and drops off only in proportion to the current instead of dropping off in proportion to the square of the current as in the preceding method. A disadvantage which it has in common with most other methods using electrodynamic instruments as detectors is that it requires a polyphase auxiliary source of voltage.

We now come to the class of absolute balance methods in which some effects of the primary and of the secondary currents are balanced against one another as a means of determining their ratio and phase displacement.

Mutual Inductance Method. (13) In this method the primary and secondary currents respectively are sent through the primary windings of two large mutual inductors. These are chosen so that the value of each mutual inductance is inversely proportional to the nominal value of the current which it carries, and hence the secondary electromotive forces induced are approximately equal. The secondary coils of the two mutual inductors are connected in series opposition so that the difference in the induced e. m. f. is applied to a detector. A fine adjustment is provided on one of the mutual inductances so that an exact balance can be obtained. In order to compensate for the phase angle of the transformer, a small resistance of a few hundredths of an ohm is connected in series with the secondary circuit of the transformer under test, and the voltage drop across a variable portion of this is inserted into the detector circuit.

This method is suitable for precise laboratory work and can be made exceedingly accurate. It is also easy to construct the mutual inductors with a considerable number of individual coils which may be connected in series or parallel. It is thus possible to obtain a wide range of values of mutual inductance and consequently a wide range of transformers can be tested.

On the other hand, it is very essential that the inductors be astatic since any electromotive forces induced in their secondary windings by a stray field would introduce an error directly in the ratio determination. This feature has been very successfully obtained in the apparatus designed by Fortescue, and now used by the Westinghouse Co. In this equipment a range of from 5 to 5000 amperes is obtained, and the mutual inductors have been made astatic by the use of toroidal coils for

both primary and secondary. Such a uniformly wound toroid produces no external magnetic field, and consequently will have no electromotive force induced in it even when placed in a strong external field providing the conductor producing this field does not pass through the opening of the toroid. By using a relatively large number of turns in the secondary coils, it is possible to obtain a secondary electromotive force as great as 4 volts, and an accuracy of 0.01 per cent can be obtained even while using a rugged and relatively insensitive detector. In the equipment mentioned above the necessary burden inserted in the secondary coils of the transformer by the testing equipment varies from 0.1 to 0.3 of an ohm impedance, depending upon the connections which are used. Complete astaticism requires that the marble core on which the coils are wound shall be machined very accurately to dimensions, and as a result the entire equipment is rather expensive, and so far as the writer is aware has not been duplicated in any other laboratory.

In any such apparatus it is important to make certain that the secondary electromotive force from the mutual inductor is in quadrature with the primary current.

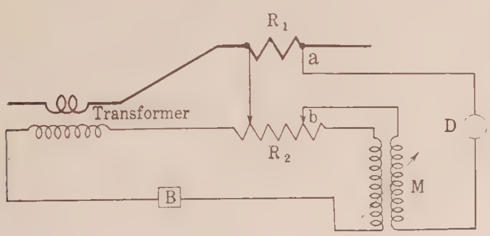

FIG. 3

Often this relation does not exactly hold in cases where the primary circuit consists of conductors of large cross section such as are necessary when heavy currents are to be measured. Fortunately the same toroidal construction which makes the inductor astatic also contributes to reduce this phase defect. (31).

Resistance Method. (1, 6, 9, 19, 20, 21, 24, 25, 28, 29, 30, 33). This method is perhaps more generally used than any other absolute method for the precise testing of current transformers. In its various modifications it is used by the National Standardizing Laboratories of the United States (1), England (33), France (19), and Germany (25), and also by several commercial and university laboratories. The primary and secondary currents are passed through four-terminal resistance standards of such value that the potential drops across the two are equal, and in most equipments of the order of one volt. The potential terminals of the shunts are then connected in series with the detector instrument so that the $I\,R$ drops are in opposition. The phase angle of the transformer is determined in several different ways at the various laboratories, depending upon the type of detector used. In one group of laboratories the unbalanced e. m. f. resulting from the fact that the primary and secondary currents are not in phase is balanced by inserting in the detector circuit a third source of e. m. f. in quadrature with the primary current. This e. m. f. may be obtained in several ways, the simplest of which is from the secondary of a small mutual inductor (1, 9, 30), the primary of which is connected in either the primary or the secondary circuit of the transformer under test. The compensating electromotive force may be obtained if preferred from a separate phase of the generator supplying the test current (19), or from a shunt circuit containing a condenser connected across the potential terminals of the primary resistor (29). With any of these arrangements the resistances and the quadrature electromotive forces are adjusted until the detector shows a condition of balance and the ratio and phase angle are then computed from the settings by the formulas

$$R = R_2/R_1 \qquad (8)$$

$$\tan \beta = \frac{\omega\, M}{R_2} \text{ or an equivalent formula.} \qquad (9)$$

In the second group of methods the effect of the phase angle is determined by the residual deflection of the detecting instrument after the $I\,R$ drops have been balanced and the detector has been excited from an auxiliary source in quadrature with the transformer currents (20, 25, 28). Slight modifications in the method as described are introduced by the type of detector which is used, but these will be discussed in a later paragraph. The method is capable of an accuracy of 0.01 per cent and can easily be made direct reading except for possible corrections to the values of the primary and secondary shunts. By suitably changing the nominal values of these shunts the method can be made very flexible, and the range can be extended indefinitely. The detector can be made sufficiently sensitive so that the voltage across the shunts is only 0.25 volt at full current, and the burden introduced into the secondary circuit can be kept as low as 0.1 ohm.

The principal objections to this method are the fact that it requires a sensitive and therefore delicate detecting instrument, and that the shunts must be carefully constructed to minimize residual inductance, and to avoid skin effect. The construction of non-inductive shunts for currents up to 1000 amperes is relatively simple but becomes increasingly difficult beyond that point (31). Precautions must also be taken to avoid errors from capacity currents which may circulate through the detector from the primary source of current.

The Baker Test Ring Method. (4) Instead of balancing the electromotive force produced by a pair of mutual inductances or a pair of resistances, as was done in the previously described methods, this method opposes the magnetomotive forces produced by the primary and secondary currents. A special test ring of well laminated transformer steel is provided with primary and secondary windings quite similar to those

of a current transformer. A third winding is placed next to the iron core and has a large number of turns (about 6000). The primary and secondary currents of the transformer under test are led through the corresponding coils around the test ring in such a direction that their magnetomotive forces are in opposition. Any departure of the currents from their nominal ratio produces a slight flux in the ring which in turn induces an electromotive force in the third winding. This third winding is connected to one coil of a wattmeter or other type of electrodynamic instrument, the other coil of which is excited from any suitable auxiliary source. The number of turns through which the secondary current of the transformer circulates is then varied until the indication of the wattmeter is reduced to a minimum. Since the number of turns of the secondary coil can be varied only in integral steps, the procedure in using the apparatus is to record the reading of the wattmeter for two different values of secondary turns near the point which gives the minimum reading. Thus, for example, if the balance point lies between 179 and 180, the readings of the wattmeter for both of these numbers of secondary turns is observed. The wattmeter is then excited from some other auxiliary voltage having a different phase from the first, and a similar pair of readings is taken. From these readings it is possible by a simple graphical construction to lay off on the drawing board the relative location of the primary and secondary current vectors with respect to the auxiliary voltages, and by interpolation between the observed points to determine the ratio and phase angle.

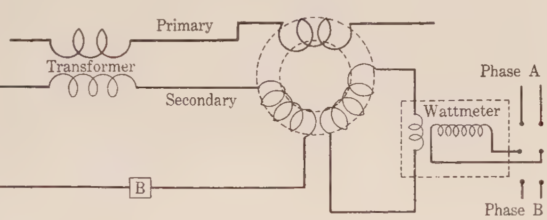

FIG. 4

This method has the advantage of requiring only simple and inexpensive apparatus, and of being quite flexible in range since the primary winding on the test ring usually consists of only a few turns which can be easily changed. The computation of the results is, however, somewhat complicated and liable to lead to blunders and the accuracy is not as high as that of the two previously described laboratory methods. Furthermore, as in all methods employing electrodynamic instruments, a separate polyphase auxiliary source is required.

The burden which the apparatus adds to the secondary circuit of the transformer consists of the resistance of the secondary coil of the test ring, which in most cases can be several hundredths of an ohm and in addition there is an effective burden resulting from any electromotive force induced in the coil by the flux arising from lack of perfect balance of the magnetomotive forces.

RELATIVE METHODS

If a standard current transformer with known ratio and phase angle and of the same nominal ratio as the transformer which it is desired to test is available, it then becomes feasible to use any one of several additional methods which have certain advantages over those previously described. Of course any of the absolute methods can be used to compare a transformer with a standard transformer of the same nominal ratio, but only those will be mentioned here in which the fact that the nominal ratios of the transformers are the same, permits of a notable simplification or increase in accuracy.

Interchanged Ammeter Method. (6, 24) A simple relative method of testing transformers is analogous to the two-ammeter absolute method first discussed, and consists in connecting two transformers with their primaries in series and with a 5-ampere ammeter and any other desired burden in the secondary circuit of each transformer. Simultaneous readings are then taken of the two secondary ammeters. The ammeters are then interchanged and a second set of readings taken. The ratios of the two transformers are then inversely proportional to the average readings of the ammeters connected to them.

It will be seen that interchange of the ammeters, which is made possible by the fact that transformers have the same nominal ratio, eliminates any error arising from a difference in calibration of the two instruments, and the absolute calibration of either instrument is of only minor importance in the test.

Of course this method gives only the ratio of the transformers and not their phase angle, and the accuracy falls off very badly at low values of the current. For the reason previously mentioned, it is not possible to use low range ammeters in making the test at the lower points on the curve. In actual tests with this method it is very important so to arrange the circuits that the secondary windings of the transformers are not open-circuited while current is flowing in the primary when the two ammeters are interchanged. A switch connected directly across the terminals of each transformer which can be used to short-circuit it while changes are being made in its secondary circuit is a valuable addition to any current transformer testing set-up.

Interchanged Wattmeter Method. (6, 24) This method bears the same relation to the two-wattmeter absolute method as the interchanged ammeter method does to the corresponding absolute method. It is quite simple to check the polarity of the transformers and by using an excitation for the voltage circuits of the wattmeters having a specified phase relation to the transformer currents, the results give directly the

relative performance of the transformers on a circuit of that particular phase displacement. The accuracy, however, is limited to the accuracy of reading the wattmeters and is rather poor with small currents.

Interchanged Watthour Meter or the Agnew Method. (3, 6, 10, 11, 16, 21, 24) This method is very similar to that just described except that a pair of induction watthour meters are used instead of the two electrodynamic wattmeters. The advantage of these meters is that by obtaining their registration over a run of several minutes duration, it is possible to obtain readings of greater percentage accuracy than can be done on the scale of an indicating instrument. This method was originally described by P. G. Agnew (3) and has been the subject of a number of other papers which have suggested slight improvements. At least one of the watthour meters which are used must have graduations marked on the disk, or be of the so-called "rotating standard" type in order that fractions of a revolution may be read off. It is usually desirable to operate the meters at a speed somewhat greater than normal since their accuracy is not impaired and the time of the test is shortened. This condition can be obtained by moving the drag magnets of the meters nearer the axis or by shunting them. By careful work an accuracy of better than 0.1 per cent can be obtained by this method, but the long time required for obtaining the readings of the watthour meters at each point renders the method somewhat slow. The computations involved are rather long but can be considerably simplified by the use of formulas and methods published by Craighead and Weller (10) or by Crothers and Kartak (11).

The three preceding methods are all of the deflection type, inasmuch as the entire primary and secondary effects are observed separately and compared in the computation. The advantages of relative methods of testing appear more definitely, however, in the balance methods, since we here have quantities of substantially equal magnitude and phase to be balanced.

Differential Wattmeter Method. (35) This method is based upon the principle of opposing the magnetic fields due to the secondary currents supplied by the standard and test transformers respectively. The secondary currents are sent through duplicate current windings of a wattmeter in such a direction that their magnetic effects are opposite. The moving coil of the wattmeter is then excited from an auxiliary source of voltage which may be either in phase or in quadrature with the currents in the transformers. A comparison of the indications of this instrument with that of an ordinary 5-ampere wattmeter connected with its current coil in the secondary circuit of one of the transformers and its voltage coil in parallel with that of the differential instrument serves to give the ratio and phase angle of the transformer from the equations (11) and (14) or (15) of Appendix B.

The equality of the two-current coils can be checked by a second observation in which they are interchanged or by connecting them in series opposition and sending current through them from a single transformer. This method is simple and, like other electrodynamic methods, can be used to check polarity and to obtain the effective ratio at any desired circuit power factor. The disadvantage of the method is that it requires a somewhat special instrument which can have relatively few turns in the current coils so that the sensitivity is low. As a result if an ordinary 10-ampere range wattmeter which has two current coils in parallel is used with the coils separated, the sensitivity will be of the order of 1 per cent per division at 5 amperes. It is, however, often possible to overload the current coils of a wattmeter and a suspension-type dynamometer instrument is amply sensitive to give an accuracy as great as 0.01 per cent. As a rough factory check on the performance of transformers to determine any serious mistakes in construction it is probable that this method is very useful.

Modifications of this method which hardly require separate consideration are (1) the use of a polyphase

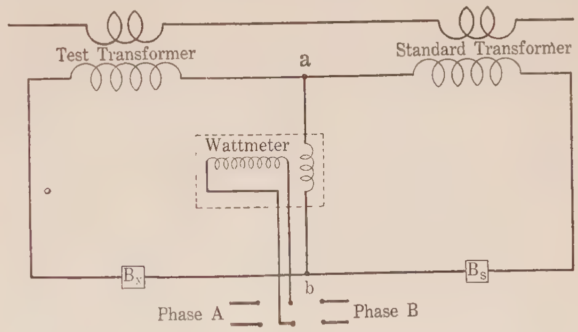

FIG. 5

wattmeter with its elements connected in opposition, and (2) the use of a differentially-wound watthour meter from which the light load compensation has been removed (35).

Bridge Circuit Method. (6, 12, 32). Instead of subtracting the magnetic effects due to the standard and test transformers, it is simpler to subtract the currents directly. This can be done by connecting the standard and test transformers with their primaries in series and with their secondaries also in series in such a direction that both transformers tend to circulate current in the same direction through both secondary burdens, as shown in Fig. 5. A "bridge" circuit is then connected between the points *a* and *b* with the result that any difference in the secondary currents of the two transformers tends to flow across this bridge and can be measured by a suitable detecting instrument placed in the bridge circuit.[1] The detector in the bridge circuit

1. This method was first described by W. A. Folger and was published in the *Proceedings* of the Pennsylvania Electrical Association in 1916, where, however, it is not widely available. It was suggested independently by the author in 1917 and published as part of Scientific Paper No. 309 by the Bureau of Standards.

can be a fairly sensitive low-range pivoted wattmeter excited from a suitable auxiliary source.

When the difference in the secondary currents of the two transformers is ΔI and the impedance of the detecting coil circuit is Z, the effective burden on one transformer is increased and that on the other transformer is decreased by an amount $Z \times \frac{\Delta I}{I}$. When the transformers are nearly equal in ratio this quantity is negligible, but when comparison is made between transformers of very different performance, the shift of the burden may become appreciable. It can be minimized by keeping the impedance of the detecting coil as low as possible. It has been found that the current coil of a one-ampere wattmeter or the voltage coil of a 30-volt wattmeter makes a satisfactory detecting circuit. It is convenient to shift the spring holders of such an instrument so as to put the zero in the middle of the scale. The scale can then be made to read directly the percentage difference in ratio of the transformers. This procedure also places the moving coil more nearly in the

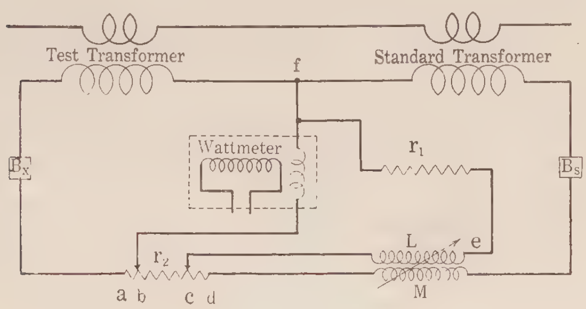

Fig. 6

position where it has zero mutual inductance with the fixed coil, and the slight errors caused by such inductance are reduced. With care this method is capable of an accuracy of 0.1 per cent in ratio and 3 minutes in phase angle.

Null Bridge Method. (32) This method is a modification of the one just described in which the uncertainty in the secondary burden resulting from impedance of the detecting instrument, and also the slight errors which may be produced by mutual inductances between the two coils of the detecting instrument have been eliminated. As shown in Fig. 6 this method makes use of a second bridge circuit, $c\ e\ f$ which is made to carry the difference in current of the two transformers. The differential current is caused to circulate through this bridge circuit instead of through the detector by suitable adjustment of the resistance r_2 and mutual inductance M. When a balance is obtained the ratio and phase angle of the test transformer are given in terms of those of the standard transformer by the following equations:

$$R_x/R_s = 1 + a + b^2/2 - b\,c \ldots = 1 + a \text{ approx.} \quad (10)$$

$$\tan(\beta - \beta) = b + a\,c = b \text{ approx.} \quad (11)$$

when $a = r_2/r_1 \quad b = \dfrac{\omega M}{r_1} \quad c = \dfrac{\omega L}{r_1}$

Unless the transformers differ widely in performance only the first terms of these formulas are of importance, and the slide wire resistance r_2 can be made to read directly the difference in ratio of the two transformers. The detecting instrument in this case may be either a vibration galvanometer or a separately excited electrodynamic instrument. In the latter case it is desirable, though not absolutely essential, that the phase of the exciting current be adjusted to coincide with that of the currents in the transformer. The magnitude of the exciting current, however, need not be known since the detector is used only as a null instrument.

In any testing method it is theoretically possible to determine the algebraic sign of the phase angle from the direction of the deflection. It is, however, in almost all cases much easier to determine this sign from a simple test based on the fact that adding non-inductive resistance in the secondary of a current transformer tends to increase the ratio and, except in very extreme cases, tends to advance the phase of the secondary current. Hence if the addition of such resistance increases the phase-angle reading the angle was originally positive before the resistance was added. If the addition of resistance decreases the phase-angle reading or reverses its direction, then the angle was originally negative. A similar test with any relative method shows which of the two transformers has the greater ratio.

Detectors

In the deflection methods the measurement is of course made directly by commercial pivoted instruments, and no unusual or sensitive detectors are needed. In the balance methods, however, special types of detector are used either as null instruments or in some cases also as deflection instruments, which serve to measure a small difference between two larger currents.

The absolute methods in general require relatively highly sensitive and therefore somewhat delicate instruments. To bring out more clearly the difference between relative and absolute methods, the case of the resistance method may be compared with the bridge circuit method. In the typical case of the resistance method the available voltage drop across the shunts is fixed at say 0.25 volt in order to keep down the burden inserted in the secondary circuit. At a secondary current of 0.5 ampere the voltage drop is only 0.025 volt, and if the ratio is to be determined to an accuracy of one part in 10,000 the detector must be sensitive enough to indicate an unbalance of 2.5 microvolts. This practically necessitates a suspension type instrument, and most detectors of this sensitivity are read by a mirror and scale arrangement.

In contrast with these, the relative methods require

in general detectors of much lower sensitivity. Thus, for example, in the case of the bridge circuit method, to obtain an accuracy of one part in 10,000 at one-tenth of rated current, the detector must show a visible indication when 50 microamperes pass through it. To compare this with the preceding case we must see what resistance the detector may have without loading the transformers with more than the assumed burden of 0.05 ohm. Even if the transformers under comparison differ in ratio by as much as 5 per cent, a current of only 0.25 ampere will flow through the bridge circuit at full current. The bridge may therefore have as much as 1 ohm resistance without adding more than 0.25 volt drop at the transformer terminals. With this resistance a sensitivity of 50 microamperes corresponds to 50 microvolts, which is 20 times the voltage which the detector for the absolute method would have to detect. Because of this relationship it is feasible to use pivoted wattmeters, such as those intended for measurements on circuits of low power factor. There are also on the market certain suspension types of pointer galvanometers which are fairly rugged, and which are decidedly more sensitive than is usually necessary, consequently by the use of such galvanometers the burden inserted in the secondary circuit can be made less than the 0.05 ohm assumed above.

For the absolute methods requiring high sensitivity, the available types of detectors are (1) the vibration galvanometer, (2) the separately excited electrodynamometer, (3) the separately excited quadrant electrometer, and (4) the d-c. galvanometer used with a synchronous rectifying commutator.

The direct-current galvanometer with rectifying commutator (7, 30), can be made the most sensitive of these instruments, and for the sensitivity required in the absolute testing methods, a fairly rugged galvanometer can be used. There are, however, a number of possible sources of error connected with its use which require a little care in their elimination. The friction of the brushes on the commutator tends to produce local heating, and thus spurious thermoelectric currents in the circuits. This error can, however, easily be eliminated by using as a zero point the reading of the galvanometer when the a-c. side of the commutator is short-circuited. Hunting of the synchronous driving motor, necessity of shifting the brushes to the proper commutating plane, and the irregularities in contact resistances are also sources of annoyance. This method also of course requires a synchronous source of fairly constant voltage from which to operate the driving motor.

A vibration galvanometer (34) can also be made very sensitive and has the great advantage that when it indicates a balance, the observer is certain that no currents of fundamental frequency are circulating in the galvanometer circuit. This is in contrast to the other forms of detector which are not sensitive to currents in quadrature with the phase of their exciting current or with the phase of the rectifying brushes. While the vibration galvanometer balances the fundamental components of the voltages produced by the primary and secondary currents in the transformer, any serious distortion of the wave form by the transformer is indicated by a blurring of the image of the lamp filament as reflected from the galvanometer mirror. No auxiliary source of voltage is required when the vibration galvanometer is used.

On the other hand, such galvanometers are mechanically rather delicate and are sensitive to mechanical disturbances, such as are caused by moving machinery in other parts of the building, so that they must be mounted on some type of vibration-free platform. Furthermore, very high sensitivity is only available over the particular narrow band of frequency to which they are tuned, and they are therefore not at all suitable for use where the frequency of the test circuit is liable to fluctuation. Another disadvantage in the use of a vibration galvanometer is that the observer cannot tell from its indications whether an observed lack of balance is due to the incorrect setting of resistance or of inductance. This objection is, however, more theoretical than actual since a relatively small amount of practise enables the observer to judge, by the rate at which the deflection of the galvanometer varies with the motion of his control handles, which variable requires adjustment; and the time required to obtain a balance with the vibration galvanometer is probably less than with the other types of instrument.

The separately excited electrodynamometer (26, 28) can be made amply sensitive for absolute methods of current transformer testing by using an instrument of the suspension type. With it the methods can be used in which the phase angle of the transformer is obtained by reading the deflection of the instrument when it is excited in quadrature with the primary current. When excited in one phase it is of course sensitive only to lack of balance in that phase, and the observer knows instantly which control to adjust. The direction of the deflection also indicates in which direction the adjustment should be made.

On the other hand, this instrument requires an auxiliary polyphase source of voltage for exciting its fixed coil, and in most methods it requires a phase shifting device for adjusting the phase of its auxiliary voltage. When it is used to measure phase angle by its deflection, it must be calibrated by some auxiliary circuit.

The separately-excited quadrant electrometer (25, 33) is very similar in its functions to the electrodynamometer, and is used to a considerable extent in Europe where such instruments are used in other branches of instrument testing work. So far as the author is aware it has not been used in this country for transformer testing. In order to obtain sufficient sensitivity for current transformer testing, the instrument has to be of

a highly refined and sensitive type, and is suitable for use only under the best laboratory conditions.

Supply of Current

Any testing equipment for current transformers must be able to supply the full-rated primary current to the transformer. Since it is usually undesirable to draw such a large current from the 110-volt supply available in the laboratory, a stepdown transformer is generally used. For this purpose it is sometimes feasible to use an additional current transformer supplied on its 5-ampere winding and delivering heavy current through what was intended to be its primary winding. In tests by the relative method in the field where it is possible to connect the two transformers in series by connecting the standard transformer across a disconnecting switch or some other gap in the line, it is quite feasible to use the actual load on the circuit as a source of primary current. Moderate fluctuations in this current will not seriously interfere with the measurement since the relative ratio and phase angle of the transformers change only slightly for a considerable change in operating current.

The wave form of the supply circuit is not of much importance because most current transformers reproduce very faithfully, in their secondary, even a very distorted primary current wave, consequently the ratio of the fundamental components of the currents is very nearly the same as the ratio of the root-mean-square values, and tests by the various methods described in this paper give substantially the same results. It is usually convenient to read the current in the transformers by means of an ammeter in the secondary circuit. Because of the small deflection of a-c. ammeters on low currents, however, it is often desirable to insert an ammeter in the primary circuit to measure the current when the secondary current is one ampere or less.

The low resistance of the primary circuit which carries the heavy current and the appreciable reactance of the primary windings of the transformers combine to produce a considerable phase shift in the primary current as compared with the source of voltage which supplies the stepdown transformer. For this reason it is very desirable to employ some form of phase-shifting device so that the auxiliary voltages used in exciting the detector instruments can be adjusted to be in phase or in quadrature respectively with the primary current. Such a shift of phase is essential in cases where the phase angle is determined by reading the deflection of the electrodynamometer instrument, or in cases where the test is used to give the combination of ratio and phase angle corresponding to the effective ratio of the transformer on a circuit of specified power factor. In the null method the need for a phase shifter is not so urgent but nevertheless it adds greatly to the convenience and speed of operation.

Brooks Type Transformer

The methods which have been discussed above are directly applicable only to transformers of the usual type with single primary and secondary windings. When used with compensated transformers of the Brooks type (8) certain modifications are necessary. These transformers have both a main and an auxiliary secondary coil and the method of test must be such as to compare the vector sum of the currents in the two secondary coils with the primary current, or with the secondary current of a standard transformer.

The resistance method can easily be modified by inserting into the detector circuit the voltage drop across a third shunt, which is connected in series with the auxiliary coil of the Brooks transformer. Since under normal conditions the current supplied by the auxiliary coil is only a small fraction of the main secondary current, the third shunt need not be adjusted to have precisely the same resistance as the main secondary shunt, but may be left at the nominal value of the latter.

The interchanged watthour meter and differential wattmeter methods can be applied to a Brooks transformer if the instruments used are provided with an additional winding to receive the auxiliary coil current. Care must, however, be exercised to avoid introducing an excessive mutual inductance within the instrument between the main and auxiliary secondary coils since this will affect the performance of the transformer. This effect of mutual inductance is probably sufficient to make the Baker test ring method inapplicable for such transformers.

The bridge circuit method can be applied to the Brooks type transformer by connecting the auxiliary coil directly across the terminals of the detector. Since the e. m. f. across the detector is small this does not seriously affect the operation of the transformer. Trouble arises, however, in the null bridge method if there is any contact resistance at the slide wire since the $I R$ drop of the auxiliary current flowing through this contact is likely to affect the detector indications. This source of error can be avoided by using a detector which has an additional coil magnetically equivalent to that used as the "bridge" but insulated from it. Even with this modification the null bridge method does not measure the true effective ratio of the Brooks transformer with rigorous accuracy. The errors, however, are very small since they involve the product of the small percentage difference of the transformers under comparison, multiplied by the small percentage compensation that the auxiliary coil supplies to the main secondary coils.

The fact that transformers of this type have such

very small ratio and phase-angle errors over a wide range of current renders them very useful as standards for use with the relative testing methods.

Miscellaneous and Indirect Methods

In addition to the direct methods of measurement described above, certain others have been suggested as being of value in special cases. For instance an a-c. potentiometer (14) may be used to measure separately the voltage drops across the shunts as used in the resistance method, and the resulting triangle of vectors can be solved to give the ratio and phase angle. A power-factor-meter or phase-meter (15) can be used to measure the phase of the primary and secondary currents respectively with respect to a polyphase voltage system, and the difference gives the phase angle of the transformer. Suitable modification of the instrument may be made so that the pointer magnifies the angular displacement by a factor of 5 or more.

In the case of transformers of very large primary current rating it is sometimes necessary to resort to the indirect process of measuring the magnetizing and core loss components of the exciting current of the transformer and computing the ratio and phase angle of the transformer from these data (5). Numerous formulas are available (2, 5, 18, 21, 22, 27) for making this computation, but the results are liable to considerable error because of lack of knowledge of the leakage reactance of the secondary winding. The presence of this reactance makes the terminal secondary voltage of the transformer when in normal operation differ materially from the induced voltage due to the core flux; and thus makes it difficult to determine at what flux density the transformer normally operates. In cases of this kind it is usually preferable to insert a number of primary turns, and thus reduce the primary current rating for the purpose of the test.

Summary

The foregoing survey of the available methods shows that the two-ammeter and two-wattmeter methods are the simplest and least accurate. The relative methods all combine considerable accuracy with fairly simple and rugged apparatus, and are probably to be preferred (1) for testing in the field or station where laboratory facilities are limited and (2) for production tests where large numbers of transformers of the same nominal ratio are to be inspected. The balanced absolute methods are of the highest accuracy but are applicable mainly in the laboratories of government and educational institutions and of the large manufacturers and central stations where they can be applied to the testing of transformers which are later to be used as standards for some relative method.

Acknowledgement

This paper has been prepared under the auspices of the Bureau of Standards, and is published with the approval of the Bureau.

A WATER-COOLED X-RAY TUBE

A new water-cooled, high voltage, X-Ray tube, developed by Dr. W. D. Coolidge of the General Electric research laboratory, has received a hearty medical endorsement, following a thorough trial in cancer treatment by Dr. James T. Case, a prominent X-Ray specialist of Battle Creek, Michigan. Doctor Case installed one of these tubes in the radiotherapy department of the Battle Creek Sanitarium in the summer of 1923, where a large series of animal experiments was undertaken. Since the first of August, 1923, all the clinical material requiring roentgenotherapy at that institution was handled with the new tube.

Radiation from X-Ray tubes has been, for many years, used in cancer treatment. For some time these tubes were of comparatively low output and their successful use was confined to the treatment of tumors not too deeply seated. The development of the original Coolidge tube gave the X-Ray specialist a much more powerful tube and, in 1921, Dr. Coolidge brought out a new design capable of operating at higher voltage (200,000 volts maximum), which, because it gave radiations of shorter wave length and consequently greater penetration was more adapted for treating deep-seated cancer.

But even with this tube, with a power output of more than a kilowatt, the treatment for cancer was long and tedious, the patient being forced to remain still for sometimes three hours or more—often in uncomfortable positions—and it therefore seemed desirable to develop a tube with a still higher power output, in order to shorten the time for treatment. To bring this about, Dr. Coolidge devoted himself to the development of an X-Ray tube for this purpose, of a greater power than any hitherto known. By increasing the voltage and the current through the tube, he knew that the intensity of the rays would be correspondingly increased. The problem was to design and produce a tube capable of carrying continuously a greatly increased load.

Accordingly, after some time devoted to experiments and research work, he first produced a tube with an anode or target made of a large flat plate of tungsten with sufficient surface to radiate continuously the energy absorbed when the tube was operated at 30 milliamperes and 200,000 volts. The tube was operated in an oil bath, which was water-cooled. It was described in a paper read before the Radiological Society of North America in December, 1922. But, although this new tube gave about four times the output of prior tubes, Dr. Coolidge continued his work until he had developed a still more powerful tube (250,000 volts, 50 milliamperes), again multiplying the output by four or, in other words, having an X-Ray output about fifteen times that of the tubes then in use for cancer treatment.

The new tube is equipped with a water-cooled anode, a seamless metal tube being utilized to conduct the water in and out of the X-Ray tube.

The Function and Design of Horns for Loud Speakers

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Review of the Subject.—*A discussion of the function of the horn, together with theoretical consideration as to the design of the horn to perform this function in the best way are given. In the body of the paper, a proof is given to show that the exponential increase in section gives the best results. For this reason, a large part of the appendix is given to the analytical solution of sound propagation in exponential horns. From the results of this work and the well known equations relating first order effects in the telephone receiver, formulas are developed which make possible the design of horns.*

CONTENTS

I. Introduction

With the growth of radio broadcasting and the development of public address systems, the electric loud speaker has come to be an apparatus of general interest. A very important part of a loud speaker is its horn, which when properly designed can greatly increase the acoustic power delivered, and go a long way towards minimizing the distortions arising from the inherent inertia and stiffness of the moving parts of the receiver. The purpose of this paper is to discuss the function of the horn, and how it should be proportioned to best perform this function.

For perfect reproduction from a loud speaker two requirements must be met: (1) a current of a given frequency must produce sound of that frequency and that frequency only; and (2) the power radiated in the form of sound must be proportional to the square of the current independent of frequency. This assumes that the available current is an exact reproduction of the pressure of sound applied to the microphone.

Several things are responsible for the introduction of extraneous frequencies. (1) If the diaphragm is insufficiently damped, the transient in the building up of vibrations will always contain the frequencies corresponding to the free vibrations of the system. This is readily eliminated by damping. (2) Double frequency may be introduced if the alternating variations of flux are not small compared to the permanent flux. This is made negligible by employing strong permanent fields. Modern balanced magnetic constructions of receiver elements were devised principally to provide for a large permanent flux without increasing the mass of the vibrating system excessively. (3) If the diaphragm deflections are large, extraneous frequencies will be introduced because of the non-linear characteristics as to restoring force and magnetic pull. Proper design of the horn will allow ample sound radiation with small diaphragm displacement and thus overcome this difficulty. So the first requirement for perfect reproduction may be closely approached.

The second requirement for perfect reproduction, that of a uniform response characteristic over the acoustic frequency range, can not be met with present day receiver elements. Variations in acoustic power of the order of ten to one between 200 and 4000 cycles are not noticed by the ear, however, and the departure from a uniform response can be kept within this range by proper design of the horn.

Contrary to the prevalent conception, the horn does not merely gather up the sound energy from the receiver and concentrate it in certain directions. Its relation to the diaphragm is much more intimate. It causes an actual increase in the load on the diaphragm, making it advance against a greater air pressure, and withdraw from a greater opposing rarefaction. Anyone can assure himself that the average sound energy in a room is greatly reduced on removing the horn from a good loud speaker. And frequently when the horn is removed the amplitude of vibration of the diaphragm becomes so great that it strikes against the pole pieces. A receiver element without a horn is analogous to a motor without a connected load; or better yet, a receiver element without a horn is like a closed oscillation circuit from which little radiation takes place (radiation resistance zero); while with a horn it is like an open oscillation circuit with an antenna (radiation resistance considerable). The horn is the antenna of the loud speaker.

In order to load, a horn need not resonate. Resonances of course increase the loading at certain frequencies, but cannot be made to provide uniform loading over a wide range of frequencies. That a horn can load without resonating is shown by the increase in sound radiation at the high frequencies where air column resonances are of small intensity. Resonances in the horn due both to material vibration and air column vibration being undesirable because of the distortion they produce, and being entirely unnecessary, should be reduced to a minimum.

Abridgement of a paper presented at the Midwinter Convention of the A. I. E. E., Philadelphia, Pa., February 4-8, 1924. Complete copies available to members on request.

Proceeding now to the detailed consideration of the function and design of horns for loud speakers we may set down three requisites.

1. A given applied force acting on the diaphragm must cause the air at the throat of the horn to have a nearly uniform velocity over the acoustic frequency range. Proper design of the air chamber above the diaphragm and the initial area of the horn will bring this about.

2. The area of the mouth of the horn must be such that only a small part of the sound is reflected back at that point, because reflections cause air column resonances.

3. The law of increase and the rapidity of increase of section must be such that:

(a) The most complete propagation of sound energy shall take place, and

(b) For a given air velocity at the throat, the power shall be nearly constant as the frequency is varied.

II. Throat Area and Diaphragm Chamber Volume

As we have indicated above, the horn is a radiator of the power which it causes the diaphragm to deliver. We may, therefore, well begin by considering the simplest sound radiating system, namely, a uniform straight tube infinitely long in one direction. Any air disturbance at the end of such a tube is propagated unchanged along the tube. In Fig. 1 suppose the piston is moved to the right. The air immediately ahead is given a velocity. Because of the elasticity of the air it is also compressed in the region next to the piston. Suppose the piston is stopped. There is now a region of pressure and in that region the air has a velocity to the right. The volumetric rate of flow of air into the region just ahead is greater than the volumetric rate of flow out, and so the pressure there rises. As long as the pressure behind is greater than the pressure ahead, the air ahead will be accelerated. When the two pressures become equal there will be no further acceleration. As the air ahead reaches a higher pressure the air behind will be retarded, and will finally reach a condition of zero velocity and normal pressure. Pressure and velocity are thus propagated along the tube. That propagation takes place in only one direction is shown by the fact that the velocity of the air is always in one direction, and that pressure can rise only when air is flowing into a region faster than it is flowing out. If the piston is moved to the left the propagation of disturbance will be in the same direction, but the pressure and velocity of the air will be reversed.

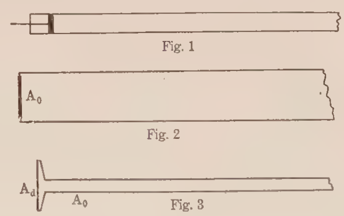
From this discussion it is seen that in a traveling sound wave, pressure and velocity are associated together in time and space phase. Neither can exist without the other. If P is the increase in pressure above atmospheric at any point, and the average air velocity at the same point and at the same time is v, $P = (\rho\, a)\, v$, where ρ is the density of air, a is the velocity of sound in air, c. g. s. units being used.

Suppose in place of the piston there is a diaphragm as in Fig. 2, and for simplicity assume that every part of it vibrates through the same distance. If when it vibrates the air is given a velocity v at a certain instant, the total reaction force over the face of the diaphragm will be that due to the developed pressure, so that

$$F = P\, A_0 = (\rho\, a)\, v\, A_0.$$

If the initial construction of the loud speaker were made in this way it would not be possible to make this force comparable with the stiffness and inertia forces of the diaphragm at the low and high frequencies, respectively. Hence the motion of the diaphragm would be determined almost entirely by its own mass and stiffness, and its motion at its resonant frequency would far exceed that at other frequencies. Hence, also, the power radiated at the resonant frequency would greatly exceed that at other frequencies.

Suppose the arrangement is changed to that of Fig. 3. Here a small velocity of the diaphragm gives the air in the tube a large velocity and much higher pressures are therefore developed. Thus this arrangement, by the principle of the hydraulic press, increases the reaction force on the diaghragm so that it may be



Figs. 1, 2 and 3—Simple Sound Radiating Systems

made comparable to the stiffness and inertia forces of the diaphragm.

An approximate formula for determining the quantity known as acoustic damping will now be derived. If in Fig. 3 the edge of the diaphragm is clamped and F is the single force acting at the centre of the diaphragm which is equivalent to the total pressure reacting on it,

$$F = (A_d/3)\, P \text{ approximately.}$$

Assuming that when the diaphragm vibrates with velocity, $\dot{u}$, the volumetric rate of displacement of air is, $A_d/3\, \dot{u}$, the velocity of air in the tube, assuming all the displaced air gets into the tube will be,

$$v = A_d/3 \quad \dot{u}/A_0.$$

From the relation between P and v,

$$F = \frac{\rho\, a}{9}\, (A_d^2/A_0)\, \dot{u}$$

Acoustic damping will be defined as equivalent reaction force per unit diaphragm velocity

$$\alpha_a = F/\dot{u} = \frac{\rho\, a}{9}\, A_d^2/A_0$$

In appendix II α_a is determined more accurately, but for the present this formula will be used to illustrate the point.

That a large value of α_a is desirable may be shown as follows. If β_0 and m are the diaphragm stiffness and mass respectively, and α_0 the internal damping,

$$\dot{u} = \frac{\text{force}}{(\alpha_0 + \alpha_a) + j\,(\omega\, m - \beta_0/\omega)} \quad \text{where,}$$

$\frac{\omega}{2\,\pi}$ is the frequency of the sinusoidal force driving the diaphragm. This is analogous to the equation for current in an electrical circuit,

$$i = \frac{\text{e. m. f.}}{(R_0 + R_a) + j\left(\omega\, L - \frac{1}{\omega\, C}\right)} \text{, where,}$$

R_0 is the internal resistance of the generator and R_a the load resistance, L and C being series inductance and capacitance. In the electrical case the power dissipated in the load is

$$W = i^2\, R_a.$$

Similarly in the acoustic case

$$W = \dot{u}^2\, \alpha_a.$$

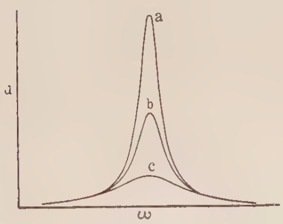


Fig. 4

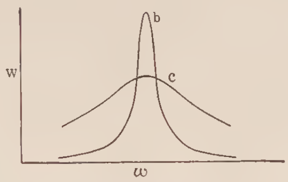


Fig. 5—Diaphragm Resonance

If α_a is zero $\dot{u}$ plotted against ω will be as shown in Fig. 4a. The radiated power will be zero. If α_a is increased $\dot{u}$ will be as in Fig. 4b—lower at resonance but about the same at the extreme frequencies. In this case W will be as in curve 5b. Now let α_a be increased still further. The velocity $\dot{u}$ becomes as in 4c, and the radiated power as in 5c. A more uniform radiation of power is secured over the frequency range, and yet the average over the range is about the same.

From the simple formula for acoustic damping it is seen that to increase it we must decrease A_0. Two effects give a lower limit to A_0, however. First frictional losses in small tubes become great. Second, if the throat is made very small the air instead of being forced out into the tube will be compressed in the chamber above the diaphragm. To prevent this the chamber volume must be decreased, and there is a physical limitation here.

Neglecting frictional losses it is shown in appendix II, that if the radiated power at two extreme frequencies $\frac{\omega_1}{2\,\pi}$ and $\frac{\omega_2}{2\,\pi}$ is to be $1/n$ times that at resonance $\frac{\omega_r}{2\,\pi}$, the area of the throat of the horn and the volume of the chamber above the diaphragm are determined by,

$$A_0 = \frac{\rho\, a}{9}\sqrt{n-1}\,\frac{A_d^2\,\omega_1}{\beta_0}$$

$$V_0 = A_0\,\frac{\omega_r^4 - \omega_1^2\,\omega_2^2}{\frac{\rho\, a}{p_0}\,\omega_1\,\omega_2^2\left(-\frac{\omega_r^2}{\sqrt{n-1}} + \sqrt{\frac{n}{n-1}\,\omega_r^4 - \omega_1^2\,\omega_2^2}\right)}$$

The following sample calculation will show relative values. Assume

$A_d = 15.5$ cm.^{2}
$\beta_0 = 20 \times 10^6$ dynes/cm.
$\omega_1 = 2\,\pi \times 200$
$\omega_r = 2\,\pi \times 1000$
$\omega_2 = 2\,\pi \times 4000$
$n = 10$

Substituting in the formulas,

$A_0 = 0.2075$ cm.^{2}

If circular in section, the diameter,

$d_0 = 0.514$ cm. $= 0.202$ in.
$V_0 = 0.258$ cm.^{3}

These values of A_0 and V_0 are much smaller than have been used heretofore.

The fact that greater acoustic damping is provided by horns having small throat areas, means that the same sound radiation takes place with smaller diaphragm velocities, and hence smaller diaphragm deflections. This will prevent the introduction of extraneous frequencies due to non-linear characteristics of large deflections.

III. Final Opening or Mouth of Horn

The infinite straight tube which we have just been considering loads the diaphragm, and conducts away the resulting acoustic power. It does not, however, communicate this power to surrounding space, and thereby fails to fulfill completely the function of a horn. Evidently the tube must be made to open up into the atmosphere. We are thus led to consider what happens at the open end of a finite tube.

Consider a half wave length of sound, in which there is positive pressure and forward velocity traveling along the tube. While progressing within the tube it is uniformly confined and occupies a constant volume. Hence the pressure and velocity in it remain constant. As it leaves the open end of the tube, however, it expands into an approximately hemispherical shape, Fig. 6a. There is thus an increase in the volume occupied by the wave as it leaves the tube. Evidently a fall in pressure must result. But if the pressure just outside the tube remains lower than that within the tube, the velocity of the air just within the tube will be

increased; this causes the pressure just behind to decrease, and the velocity to increase, and so we have produced a wave traveling back in the tube, which near the open end reduces the pressure and increases the velocity in the oncoming wave. This is the familiar phenomenon of reflection.

The reflected wave not only represents power which does not get out into the air but, depending on the phase in which it reaches the diaphragm, it may produce resonance or dissonance. Obviously the less intense the reflection is, the less marked will be the resonance or dissonance.

It is now easy to see what influence the size of the final opening of the tube has upon the intensity of the reflection. It is evident from Fig. 6A that the larger the section of the tube is, the less will be the relative increase in volume occupied by a half wave length just within and just without the tube, and therefore the less intense will be the reflection. For wave lengths which are less than the diameter of the tube, Fig. 6B, the increase in volume on passing out of the tube is slight, and therefore the reflection is negligible; but for wave lengths which are greater than the tube diameter, Fig. 6A, the increase in volume becomes considerable, and the reflection becomes appreciable.

Thus a horn, to transmit a 500-cycle wave with wave length 68.8 cm. to the atmosphere without reflection would need to have a final opening of diameter about 70 cm.

For many purposes this is an inconveniently large diameter, and it is therefore interesting to determine

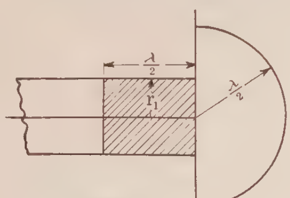


Fig. 6a

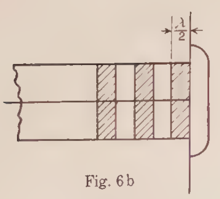


Fig. 6b

FIG. 6—ILLUSTRATING REFLECTION

how much is sacrificed by using a smaller final opening. An approximate calculation for wave lengths greater than the tube diameter is easily made.

Let P_1, P_2 and $-P_r$ be the pressure in the oncoming, transmitted and reflected waves, respectively. The excess of air in the oncoming half wave length which causes the rise of pressure P_1 is passed on into the transmitted half wave length causing a rise of pressure there. The reflected half wave length, with its negative pressure also draws air out of the tube and into the transmitted hemispherical half wave length. This mass of air which is taken from the half wave length within the tube and transferred to the half wave length outside the tube, causes a reduction in pressure within equal to $P_1 + P_r$, and an increase of pressure outside equal to P_2. Since these two pressure changes are inversely proportional to the volumes involved, we have

$$\frac{P_1 + P_r}{P_2} = \frac{2/3\ \pi\ (\lambda/2)^3}{\pi\ r_1^2\ \lambda/2} = 1/6\ \lambda^2/r_1^2\text{, where}$$

λ is the wave length, and
r_1 is the radius of tube.

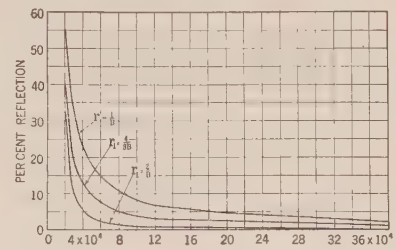


FIG. 6C—VARIATION OF REFLECTION

Furthermore, $P_2 = P_1 - P_r$, so that finally,

$$P_r = \frac{\lambda^2 - 6\,r_1^2}{\lambda^2 + 6\,r_1^2}\ P_1$$

If $\lambda = 68.8$ cm. corresponding to 500 cycles and $r_1 = \lambda/4 = 17.2$ cm.

$$P_r = P_1 \left(\frac{1 - 6/16}{1 + 6/16} \right) = 0.45\,P_1$$

In Appendix IV an approximate determination of reflections is given for the exponential horn in which the area at any distance x from the small end is given by

$$A = A_o\,e^{Bx}$$

where B is a constant which determines the rate of increase. The curves of (Fig. 6C) show how the reflection varies for different values of $\omega\,B$, and final radius r_1 of the horn. These curves also indicate that the larger the final radius and the higher the frequency, the less the reflection.

IV. SHAPE OF HORN

We have now shown that to load the diaphragm effectively the initial opening or throat of the horn must be small, and to communicate the resulting acoustic power effectively to the atmosphere, the final opening or mouth of the horn must be large. We must now consider how these two extremities are to be joined; what the length of the horn should be, and according to what law the section should increase.

Consider a uniform straight tube which at a certain point opens up abruptly into a second uniform straight tube of larger section. A sound wave in the first tube propagates in the simple manner described under section II. At the point of sudden change of section more complicated conditions appear, but beyond this point, in the second tube, simple propagation again

takes place. As is well known, the ultimate result of the discontinuity is a reflection, which reduces the energy which passes on to the second tube. Furthermore, the magnitude of this reflection is proportional to the *relative* increase in section at the point of discontinuity, that is to $\frac{A_2 - A_1}{A_1}$, A_1 and A_2 being the sectional areas of the tubes respectively. We may then say that the departure from simple propagation is proportional to the relative increase in section.

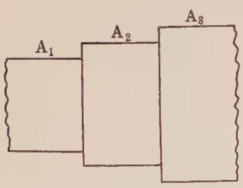


Fig. 7—Discontinuing in Straight Tube

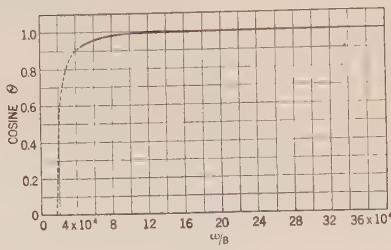


Fig. 8—Variation of Loading in Exponential Horns

Returning now to the horn, with continuously increasing section, it seems fairly reasonable to suppose that at each point, the departure from simple propagation will depend on the *relative* increase in section per unit length, that is to $1/A \frac{dA}{dx}$. The initial and final section areas having been determined, the total relative increase in area is prescribed. All this being granted, it seems entirely reasonable to suppose that the best horn will be one in which this relative increase in area is uniformly distributed over its whole length, rather than one in which the relative increase in area is large at some points and small at others. Thus we conclude that for the best horn, $1/A \frac{dA}{dx}$ is constant along its length. To have this property, the sectional area must increase exponentially with the length, that is

$$A = A_0 e^{Bx}$$

We may give a more quantitative turn to this argument as follows. Consider two discontinuities in a straight tube as shown in Fig. 7, the areas of the three sections being A_1, A_2 and A_3. A wave having air velocity v_1 in passing from A_1 into A_2 is partially reflected. Let v_{1r} be the velocity in the reflected wave and v_2 be the velocity in the transmitted wave. Similarly in passing from A_2 into A_3 let v_{2r} be the velocity in the reflected wave and v_3 the velocity in the transmitted wave. Let P with the corresponding subscripts represent the pressures associated with each of these velocities.

$$A_2 v_2 = A_1 v_1 - A_1 v_{1r}$$
$$A_3 v_3 = A_2 v_2 - A_2 v_{2r}$$
$$P_2 = P_1 + P_{1r}$$
$$P_3 = P_2 + P_{2r}$$

Because of the constant ratio of pressure to velocity in straight tubes, the last two equations become

$$v_2 = v_1 + v_{1r}$$
$$v_3 = v_2 + v_{2r}$$

From these four equations we may eliminate v_{1r}, v_2 and v_{2r} and obtain

$$v_3 = \frac{4 A_1 A_2}{(A_1 + A_2)(A_2 + A_3)} v_1$$

If v_1, A_1 and A_3 are fixed, v_3 will be maximum, if

$$A_2 = \sqrt{A_1 \times A_3}$$

This again leads to the exponential horn.

In Appendix III, with certain approximations, the characteristics of the exponential horn are determined analytically. Pressure and velocity have the same absolute ratio as in the straight tube; but are out of phase by an angle whose cosine is a function of ω/B. Curve Fig. 8 shows the plot of this cosine. It approaches unity (or the straight tube radiation characteristic) if ω is large enough or B small enough. In section I it was shown that a sufficiently uniform power radiation characteristic could be obtained with the straight tube if its section were made small compared to the area of the diaphragm. With the exponential horn having the same throat area, neglecting reflections at the open end, the power will differ from that of the straight tube by the cosine of the angle between pressure and velocity. Since this cosine begins to fall off rapidly below

$$\omega/B = 2.5 \times 10^4,$$

if the radiation is to be uniform down to 200 cycles, corresponding to $\omega = 1257$, B must be less than $\frac{1257}{2.5 \times 10^4}$ or approximately 0.05. This value of B gives a horn which opens up very slowly. Since the

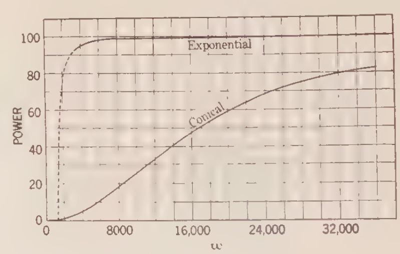


Fig. 9—Comparison of Loading of Exponential and Conical Horns

initial area must be small and the final area reasonably large, this small value of B will result in a long horn.

The superior radiating power of the exponential horn is well brought out by comparing it with a conical horn of the same initial and final areas and the same length. Assuming circular sections, let the

initial section radius, $y_0 =$ 0.254 cm.
final " " $y_1 =$ 14.3 cm.
length l = 115 cm.

For the exponential horn, this gives $B = 0.07$. The conical horn will have an angle whose sine is 0.122.

From the equations given in Appendix III, the power propagated at various frequencies for a given velocity in the throat may be calculated. The results are shown in Fig. 9, expressed in per cent of the power for high frequencies which is the same for the two horns. This is a positive indication of the advantage of the exponential horn over the conical.

V. Experimental Work

In the experiments to be described, the several horns shown in the photograph (Fig. 10) were arranged so that a receiver element could be quickly transferred from one to another for comparison. Horn No. 1 is a pyramid 4½ feet long, with initial and final areas 0.0315 and 324 square inches respectively. Horn No. 2 is an exponential horn of the same terminal areas and about the same length. The percentage increase in area per inch is about 20, corresponding to $B = 0.07$ for centimeter units of length. The lower part of this horn may be removed or replaced by the straight extension of diameter 1¼ in. and the same length shown to the right. Horn No. 3 is an exponential horn having the same initial and final areas as horn No. 2, but the percentage increase per inch is about 35, corresponding to $B = 0.12$.

Fig. 10—Horns for Experimental Comparison

Experiment I. To compare the loading of conical and exponential horns. Horns 1 and 2 as shown were compared. A receiver having a resonance at 2200 cycles was connected to an audio frequency oscillator. At frequencies below 1500 cycles or above 3000 cycles, it is assumed that the addition of a horn will not materially alter the velocity of the diaphragm. Under such circumstances, the horn having the greatest value of acoustic damping will radiate the most sound.

At each frequency the receiver was placed first on one horn and then on the other. From 250 to 500 cycles the response of the conical horn was weak, while the exponential was very strong. As the frequency was raised the response of the conical increased. Above 3000 cycles the difference was much less marked, being only slightly in favor of the exponential. This test substantiates the curves of Fig. 9.

Experiment II. To compare exponential horns having different rates of increase. Horns 2 and 3 as shown were compared. Using the same receiver, and gradually lowering the frequency from 1000 cycles, the two horns radiated nearly equally until about 350 cycles frequency was reached. At this point the response from horn No. 3 fell off abruptly and remained low down to 250 cycles, the lowest frequency of the oscillator used. The quantity ω/B for the small horn at 350 cycles is 18,300. This value of ω/B corresponds closely to the point on curve of Fig. 8 where the loading falls off.

Experiment III. To determine the effect of changing the initial opening, keeping the rate of increase the same. Horn No. 2 was used with and without the lower part. A receiver having its diaphragm resonance at 500 cycles was employed. Below and above resonance the response was much greater using the extension. At resonance the rattle and blasting produced without the extension was entirely eliminated with the extension. These results indicate greater loading with the extension.

Experiment IV. To show that increase in loading in Experiment III was due to reduction of area and not to increased length. The upper part of horn No. 2 was used with and without the straight section shown to the right; and then first with the straight extension and then with the exponential extension. Very little difference was noticed with and without the straight section. About the same response was observed below and above resonance and the same blasting at resonance.

Comparing the horn first with the straight extension and then with the exponential extension gave results similar to those of Experiment III, indicating that the addition of the straight part did not increase the loading.

VI. Conclusions

The following are major points in the function and design of horns for loud speakers.

1. The purpose of the horn is to load the diaphragm, and to radiate the power which it causes the diaphragm to deliver. Great loading is required in order to smooth out diaphragm resonances; and to allow ample sound radiation with small diaphragm velocities, thereby reducing extraneous frequencies introduced when diaphragm displacements are beyond the range of linear characteristics.

2. The exponential horn in all probability provides greater loading than any other horn having the same length and terminal dimensions. Experiment I confirms this in the case of the conical horn.

3. The maximum loading of an exponential horn on a given receiver is determined entirely by its initial area, the loading increasing with decrease in area until friction beings to play an important part. This assumes that the chamber volume above the diaphragm is small so that most of the air is forced out into the horn instead of being compressed in the chamber. Experiments III and IV show that decreasing the throat area increases the loading. Experiment II shows that

above a certain frequency, two horns having different rates of increase but the same initial area will provide the same loading.

4. The uniformity of loading of an exponential horn is determined by its rapidity of increase in section, the less the rate of increase, the more uniform the loading. Uniform loading may be expected down to the frequency where $\omega/B = 2.5 \times 10^4$ approximately. Experiment II showed that when ω/B was reduced to 1.8×10^4 the loading fell off considerably.

5. The larger the final opening, the less pronounced will be the horn resonances. The intensity of resonances decreases with increase of frequency. It has been found that, in exponential horns, the resonances are hardly noticeable above the frequency when the horn begins to load if the final section is over 14 in. in diameter.

In loud speakers with horns designed according to the data contained in this paper, the reproduction of music is not just pleasing but close to the original, and the reproduction of voice is not only intelligible but natural.

Discussion at Pacific Coast Convention

MECHANICAL ELECTRICAL CONSTRUCTION OF MODERN POWER TRANSMISSION LINES—INSULATORS FOR HIGH-VOLTAGE LINES[1]

(Carlson and Battey),

SPECIAL FEATURES IN THE DESIGN OF TRANSMISSION TOWER LINES AS IMPOSED BY ELECTRICAL CONDITIONS[2] (Dreyer),

Del Monte, Cal., October 3, 1923.

E. V. Pannell: Mr. Dreyer, on the fourth page of his paper, makes particular reference to the matter of excessive swinging of insulator strings where the vertical loading disappears. On the subject of dangerous swing of insulators where the horizontal load is unbalanced, the facts seem to show that the tie-down string is somewhat unsatisfactory, but Mr. Dreyer makes no mention of the possibility of using weights and I would like to know whether he has made any experiments in this respect. The use of a weight in place of a tie-down string has the advantages that a vertical component is provided at the same time the flexible characteristics of the line are not impaired and the arrangement would seem to be inherently superior to imposing dead-end stresses on a point which is not designed as a dead-end. In several installations in this country weights are being used instead of tie-downs and I also know of work in Japan where weights have superseded tie-downs with greater satisfaction. It is necessary, of course, that clearances shall not be impaired but if this condition is satisfied I believe weights will be found the most satisfactory device.

H. Michener: On the Big Creek lines, consideration was given to the use of weights instead of tie-downs; it was finally decided that it took too many tons of cast iron. The tie-down strings on the Big Creek lines have given no more trouble than any other strings on the line, so we do not feel that they are a great hazard.

R. J. C. Wood: It seems to me that we may go too far in trying to eliminate the dead-end strings. We would like to get away without any of them largely on account of the cost, but it is a fact that on the Big Creek lines we have had less trouble on the dead-end strings than on any of the others. I think the exact record is two cases of trouble on dead-end strings in the whole operation of the line.

M. Hillebrand: I would like to ask Mr. Wood to amplify that last statement.

The reason for the elimination of dead-end strings, to my mind, holds as much today, possibly not just as much, but the fundamental reasons are the same as they always have been. That is, that the mechanical load on the dead-end string is higher than elsewhere. This tends to cracking and exists to a greater extent in the dead-end insulator than on the suspenion strings. It is in order to reduce the cracking of the insulators that it has been so often recommended to eliminate dead-end strings wherever possible.

Now, the troubles that Mr. Wood refers to, unless I am mistaken, are in the nature of flashovers through the air and around the insulator. On the other hand, I believe it is true that their records show that their insulator failures on dead-ends have been at much higher rates than those on the suspension string. Is that true, Mr. Wood?

R. J. C. Wood: Yes, it is higher.

Mr. Hillebrand: I would like to ask Mr. Dreyer just what is derived from the use of a lower string tension. That is, was it due to a lighter tower, resulting from a lower design in order to maintain a minimum clearance?

C. B. Carlson: On the point of tension, it might be added that the span, as we have made it in our line, is considerably larger than those heretofore used. This might bring that point back again to a higher tension rather than lower tension. That is, with a greatly increased span maintaining all the time a factor of thirty feet from the ground as a constant, the calculations might revert back to an advantage towards a little higher tension insofar as that is concerned.

W. Dreyer: Answering Mr. Hillebrand's question as to how the lower tension affects the tower design, the towers become lighter and the footings become lighter, almost in direct relation to the movement of the loading. The product of the loads on the tower times their distance from the ground, approximately gives the law of variation in the weight of the towers. Thirty feet of the height of the towers is put in to take care of minimum ground clearance. Seven feet more is necessary to take care of the length of suspension insulators on 220-kv. lines, giving a total height of thirty-seven feet which is necessary without any consideration of conductor stress.

In order to show how the problem would work out on a line of 220-kv. potential using 500,000 cm. copper and insulators seven-ft. long, the following table comparing maximum stresses of 27,000 and 17,000 lbs. per sq. inch respectively.

Stress—Lbs. per Sq. Inch			Sag at Min. Stress	
Max.	Min.	Broken Wire (Allowing for insulator)	Span = 800 ft.	Height to Low Wire
27,000	19,700	15,000	16 ft.	53 ft.
17,000	13,000	11,200	24 "	61 "

Using the above table as a basis, the following table shows the

1. A. I. E. E. Journal, 1923, Vol. XLII, November, p. 1126.
2. A. I. E. E. Journal, 1923, Vol. XLII, November, p. 1117.

relation between heights to center of application of leads and overturning moments for both single and double-circuit towers.

Max. Stress	Single-Circuit Towers				Double-Circuit Towers			
	Height to Center of Load	Ratio of Height	Ratio of Load	Ratio of Moment	Height to Center of Load	Ratio of Height	Ratio of Load	Ratio of Moment
27,000#0"	53	1.00	1.00	1.00	68	1.00	1.00	1.00
17,000#0"	61	1.15	0.75	0.86	76	1.12	0.75	0.84

The ratio of moment, which is nearly in proportion to the ratio of weight of towers and size of footings, shows a saving of 14 per cent for the single-circuit and 16 per cent for the double-circuit towers. This analysis is only approximate, but it indicates the existence of a point of economy for the stress in the conductor.

Regarding the affect of torsional stresses the square tower is not materially affected in weight, the torsional stresses being taken care of almost entirely by the web members.

Regarding the use of weights to prevent excessive swinging of insulator, as suggested by Mr. Pannell, we have given consideration to such an expedient. The objection was the additional electrical clearances required, which would either make it necessary to use special towers with greater clearances for the particular cases involved, or else design all towers with excessive clearance, which would be uneconomical.

110-Kv. TRANSMISSION LINE FOR OAK GROVE DEVELOPMENT OF PORTLAND RAILWAY, LIGHT AND POWER COMPANY[1]

(Wakeman and Lines),

TRANSMISSION LINE CONSTRUCTION IN CROSSING MOUNTAIN RANGES[2] (Crawford),

Del Monte, Cal., October 3, 1923.

R. J. C. Wood: We have encountered some little trouble in crossing mountain ranges in snow countries, supposedly due to the loss of the snow or sleet load from a span and the conductor coming in contact with the one above it. On the double-circuit steel tower line, in question, the conductors are offset a foot and a half from the vertical plane of the one above it. We have had considerable discussion as to just what happens to cause these conductors to come together. One theory being that the sleet falls off the one span and still remaining on the adjacent span, the lighter span is pulled up into the one above it.

Another theory is that the sleet falls off a portion only of a long span and that gives it a deformed shape sufficient to permit the two conductors to come together.

The third theory is that when the sleet falls off it sets up waves of sufficient amplitude to produce contact.

It will be interesting to know if anybody else has made observations on this subject and can give us information on just what happens when the sleet falls off.

J. P. Jollyman: We do not cross any high ranges at high altitudes or any locations subject to extremely severe climatic conditions.

We have had some sleet trouble. It has been generally thought, though not actually observed, that the sag in the conductors is greatly interfered with by the inequality in the loading of sleet. It is now believed that the conductors load up uniformly and when the sleet starts to melt the trouble begins.

We had one interesting report where sleet accumulation on spans was found to slide to the lower part of the span and pile up in very great weight at the bottom of the span. We had one or two cases of trouble which indicated that such an event had happened. The only precaution that has been taken in country known to be subject to sleet is to employ the horizontal configuration, or to employ the displaced conductor arrangements of the vertical circuit. It has been our experience thus far in points not subject to very heavy loading, that a 20-foot vertical displacement seems to be free from trouble, whereas, a 10-foot is not. In a configuration using three conductors normally spaced ten feet apart vertically, the center conductor is displaced either outward or inward two or three feet and thus far it has been satisfactory.

R. J. C. Wood: Referring to the 20-foot vertical spacing, what length of span is that?

J. P. Jollyman: We would not ordinarily regard the horizontal displacement as effective in spans of, over 500 or 600 feet. Where we have longer spans, and where we have any idea that sleet conditions will occur, we would feel it necessary to change from a vertical to a horizontal configuration, to be entirely safe from the difficulties attending on the unloading of sleet.

W. S. Jennens: Sleet does not occur on our lines on the plateau or high points in the Rocky Mountain district, in which our system is located, but mostly in the low hills adjacent to the Bear River and at those points where the cold air from the other side of the hills strikes the moisture-laden air. The condition known as sleet by most of us, is not in the form of solid ice, but chiefly in a compact form of frost. Sometimes, of course, we have damp or extremely wet snow which, in falling from the conductors, gives us the same condition as you gentlemen know as "sleet-jump." Fortunately the condition prevails mostly in short sections of the line and if the condition can be discovered in time, lines mostly concerned are taken out of service long enough to permit the maintenance crews to dislodge the wet snow by jarring the conductors. From the observation of these crews, we have concluded that there is no definite way in which the conductors act when the sleet jumps before the snow actually falls. We will find adjacent spans having entirely different appearances, one being loaded with snow, the conductors will sag down and the other span without snow, the conductors will be stretched tight and consequently rise. If, therefore, no equal loading of the conductors in the same span prevails, it will readily be seen that the conductors will come in contact with one another without the sleet having jumped. On the other hand, when the sleet does not let go through any unbalance of adjacent spans, conductors may rise in accordance with their previous loaded condition, and come in contact with each other in the third or even in the fourth span, particularly if the latter be below on a hillside where the tendancy of the conductor is to run down towards the bottom of the slope. In some cases there will be a wave motion of the conductors, as pointed out by Mr. Wood, due to snow falling in one span and its jarring effect communicated to the conductors of other spans. The result of change of tension in the various contiguous spans causes the wave of the conductor to run along the line and if two or more conductors do not act similarly, they will come in contact with each other. Where they are out of step, so far as the wave motion is concerned, it is evident that on 130-kv. line that contact made thus will quickly burn the conductor through. We find that the conductors burn chiefly in the center of the span.

Each year's condition has become worse and worse, and during the past summer we have off-set the center conductor of each circuit arranged in a vertical configuration to a distance of approximately three feet, only however in the locations where previous observations have shown the sleet to have formed to any considerable degree. We expect in the future to complete this off-setting in order to eliminate the chances of failure in any locality throughout the length of the line. On account of the design of our steel tower being such that it greatly weakens the same if we lengthen the middle crossarm or reduces the clearance to ground at the tower should we shorten the arm, we have followed the scheme in use on the Pacific Gas & Electric Company's lines, using an additional string of insulators on the middle arm to pull the conductor towards the tower.

1. A. I. E. E. Journal, 1923, Vol. XLII, September, p. 891.
2. A. I. E. E. Journal, 1923, Vol. XLII, November, p. 1121.

We are not certain whether our three-foot off-set is sufficient and would like to ask Mr. Jollyman, if, in his opinion, it is enough for operation at 130-kv.?

R. H. Halpenny: On one tower line of The Southern Sierras Power Company, some trouble resulting from sleet on conductors has been experienced, particularly at a point where the line crosses a mountain range at an elevation of approximately 4000 feet. No trouble of this nature has been noticed, however, which could be traced to the swinging together of conductors when loaded with sleet, this being due possibly to the arrangement of conductors, which offsets the middle conductor of each circuit five feet from the vertical plane in which the top and bottom conductors lie, with a resultant normal vertical separation of twenty feet between top and bottom conductors. The longest span in this section of line is approximately 1400 feet.

The most severe kind of trouble in this locality has been tower failure. Line conductors have failed due to sleet loading in a few instances but an excessive dead load of this nature has ordinarily resulted in the deformation of the cross arms or some other tower member.

This trouble has been overcome to a great extent by additional bracing of tower members showing a tendency to fail under such loading, also in some cases by the addition of towers at points liable to be most heavily loaded.

John B. Fisken: This discussion takes me back to the Vancouver Convention in 1913, at which convention the same subject was discussed. The question has been asked, and the desire has been expressed for actual testimony, as to what occurs. I can't of my own knowledge give any such testimony, and, as a general rule, I don't always believe all that the average farmer says, but we have one farmer in our region who I believe told us the truth. He gave us, some years ago, a very full description of what he actually saw. The conditions were vertical arrangement of conductors on a two-circuit tower line, the wires in vertical planes having horizontal separations of about six inches. He said that while he was passing the line one day, and this was after we had all been driven nearly crazy with the shutdowns, he saw the frost drop off one wire and that wire fly up and strike the one above it. This is not sleet loading but frost that forms and drops off when the day gets warmer. After that we separated the vertical planes of the wires horizontally by moving the top conductor in towards the tower, and lengthening the middle crossarm and moving the conductor from the tower. This gave horizontal separations between vertical planes through the conductors of top to center, 5 feet, 10 inches, center to bottom 3 feet, 5 inches and top to bottom, 2 feet, 5 inches. Since then we have had no trouble at all and I am satisfied that all of our troubles were due to the same thing, the unloading of the conductor in one span and the excessive weight of the adjoining spans causing it to hit the wires above it.

Harold Michener: Referring again to the line of which Mr. Wood spoke—I was over it on Saturday and Sunday, last, trying to determine what we could do to it. We selected a span about 890-ft. long that was held by suspension insulators at each end, calculated the load for the span with half an inch of ice, and concentrated one-fourth this load at the one-eighth and one-fourth at the three-eights points of the span. This pulled the center wire down about one foot below the bottom wire and showed that if the bottom wire should be unloaded and the center wire loaded, the center wire would go down into the bottom wire for more than three-eights of the length of the span. That was only an indication of what might happen in a territory where we had not assumed any sleet load in designing the line, and we are of the opinion that in the territory where the design assumptions include a sleet load, and, for that reason, a lower stringing tension, and where the spans are longer, the top wire would come down to the bottom wire if the top wire were loaded in one-half the span and the bottom wire unloaded. The vertical distance between top and center and bottom wires at the towers, is six feet, three inches.

H. H. Schoolfield: We have observed a very peculiar phenomena on one of our transmission lines which might be of interest to the engineers present. I have never yet been able to find a satisfactory explanation for it. Perhaps some of you gentlemen can enlighten me.

We have a 66,000-volt line, with suspension insulators, and conductors of three-strand copper clad steel. In connection with this we have a seven-strand steel ground wire. There are several places in the line where we get frost conditions similar to those described by Mr. Fisken. I call it frozen fog. It builds up on the copper clad conductors to a considerable extent and we have experienced the same trouble of wires swinging together; the lower wire flying up and hitting the upper wire. The peculiar fact is that the frost does not accumulate on the steel ground wire. I don't know why it is and I can't find a satisfactory explanation for it, but it is a fact that the frost will build up to considerable extent on the copper clad conductors, but does not build up at all on the steel ground wire.

L. J. Pospisil: In addition to what Mr. Fisken has said in regard to his experience, I want to say that in the year 1910, I believe it was, there was an effort made to reproduce the conditions, of what occurred from actual experience, by constructing two spans of a sample line and reproducing the loadings along the conductors by means of weights, and then releasing the weights and observing what took place. At that time Mr. Geiser wrote a paper on those experiments, which I think was given at the Vancouver Convention in 1913.

H. T. Plumb: The Utah and Idaho power companies have had some trouble with frost conditions; but along most of the lines it has caused no trouble. The frost referred to is a wonderful formation; it happens only in a very still valley where no wind is blowing; it builds up in the night, and disappears as soon as the sun begins to shine when it drops off. It adds considerable weight to the conductors, and their diameter may become four or even six inches. An explanation of why it might form on copper conductors more than on iron conductors is that the iron is probably smaller in diameter and the amount of growth seems to be dependent on the diameter of the thing to which the frost fastens itself.

Not long ago one of the smaller power companies in Utah had difficulty with a very wet sleet bridging over insulators and causing them to ground, or flash across. It was a sleet so wet that it could hardly be called ice and yet it would stick and build up on the lee side of an insulator.

M. T. Crawford: Experience with wires arranged in a vertical plane has been universally unsatisfactory in our territory through snow country and it should be noted that, in the line described in this paper, a horizontal arrangement was used. Longitudinal movements of the wire accompanying the vertical movements sufficient to cause short circuit with a ten-foot vertical displacement would necessarily produce severe stresses at dead end points, and it was to avoid damage from these stresses that the special form of suspension construction was employed. Since writing this paper the line has gone practically through another winter without a repetition of the failure described although ice and frost formations have been equally severe.

INSULATION DESIGN OF ANCHORS AND TOWER SUPPORTS FOR 110,000-VOLT, 4427-FOOT SPAN OVER CARQUINEZ STRAITS[1] (CORBETT,)

DEL MONTE, CAL., OCTOBER 3, 1923.

L. M. Klauber: I wish to point out one fact, namely, that a line of such importance, crossing a water way open to traffic where great clearances are necessary, would naturally involve special structures and relatively high costs. One not familiar with long spans might deem it essential that whenever such spans are constructed, regardless of the character of the line, equally expensive structures are essential. I would like

1. A. I. E. E. JOURNAL, 1923, Vol. XLII, September, p. 887.

to point out that for spans of this magnitude in less important lines, a much less expensive construction may be used with entirely satisfactory results.

For instance, it was recently necessary for our company to construct a line serving a load of only 50 kw. We have in that line one span which in length approaches this one within one hundred feet; it is approximately 4300 feet long and yet the construction is inexpensive, utilizing wood poles for towers. Of course, it is obvious that this line does not cross a waterway through which ship traffic must be accommodated and thus great clearances are unnecessary. On the contrary it crosses a rather wide canyon and had it not been for a spur of a hill that came up in the center, the span would have been 7600 feet instead of 4300 feet long. As it was we had to locate a tower in the middle on the spur between the 4300 foot span and a 3300 foot span. The line including these spans is no more expensive than an ordinary pole line following the road would have been.

H. H. Schoolfield: We have some long spans but nothing like Mr. Klauber mentioned. We have one about 2800 feet long on wood pole construction and it is no more expensive than following down the canyon.

J. P. Jollyman: The detail of the design of the re-insulation of the Carquinez crossing is not offered as a sample of how long span construction should ordinarily be made. As has been pointed out, this crossing is one over a navigable stream. The crossing was designed over twenty years ago and represents a very remarkable achievement for that period.

It is rather seldom that we find spans of that length with conductors of that character supported on rigid insulators; most of our new work is with suspension or strain insulators where the rigid points of support are at the tower and not at the conductor. In the Carquinez span, the long time success of the compression theory of insulation led us to conclude it would be a wise thing to continue and for that reason the insulators for the higher voltage were determined to be of the rigid type. A rigid form of support introduces the very pressing problem arising from the vibration of the conductor and our endeavor to terminate that vibration at a fixed point. Experience has shown the necessity of absorbing the vibration before it strikes the rigidly supported point, or in a short time, crystallization of the conductor will occur. A rather striking experience was had in this crossing. A few years ago the crossing was worked over and was changed from four wires to six wires in order to give two complete circuits. At that time it was known that some reinforcements of the original cables over the rigid supports was necessary and an attachment was put on designed to take most of the strain off the main cable. Within a few weeks crystallization occurred and a strand broke at the attachment. The attachment was several feet out from the original point of the support, but it was a little too heavy; so in redesigning the work we have taken particular precautions to add weight gradually as the point of rigid support is approached.

First we add one cable for reinforcement and a few feet further on we add a second. These cables are then attached to the main cable by means of relatively light clamps sufficient in number to take the entire strain and amply spaced, and finally the main cable with its reinforcing cables changed from the vertical to the horizontal plane, is brought to the point of rigid support. The construction has been up over a year. We have had no mechanical trouble with it whatever, or any electrical trouble except with some windows at the entrance to the anchor houses. We installed those windows thinking that they might be of some use, but they proved to be the weak point in the construction and have been removed. It is not our intent to replace the windows. We have had no mechanical trouble and I believe our experience has been sufficient to justify the assumption that the mechanical design is going to function correctly.

L. J. Corbett: There is little to add as no questions have been raised. The important link this particular crossing forms in the transmission system; the fact that it crosses a navigable waterway, a main line railway and other power and communication circuits, and the adherence to the compression type of insulation have resulted in the rather elaborate construction described. Our company has other long spans on lines in mountain districts of the type described by Mr. Klauber and Mr. Schoolfield.

I wish to emphasize the importance of the proper design of the five hinged anchor structure of Fig. 3. E_3 is the only point at which a hinge can be located on the stem of the Y. The entire Y frame between the hinges E_3, B and C, must be absolutely rigid.

WATERWHEEL GENERATORS AND SYNCHRONOUS CONDENSERS FOR LONG TRANSMISSION LINES[1]

(SMITH),

DEL MONTE, CAL., OCTOBER 4, 1923

E. B. Shand: It is desired to draw attention to the conditions of line charging by an a-c. generator. One method which has been frequently used to determine this effect consists in taking the voltage characteristics of the generator when excited by the armature current directly from the no-load saturation and the short-circuit saturation curves. By plotting the volt-ampere characteristics for the capacity effect of the external circuit, the intersection of the two curves will give the value to which the terminal voltage will rise, with the field un-excited. This method involves quite an appreciable error, due to the fact that when the generator is excited from the field, the voltage is generated only by the flux in the magnetic circuit of the armature, but when excited from the armature an additional voltage is generated due to the leakage fluxes which are not present in the other case. It is evident, therefore, that the relation between voltage and ampere turns will differ under the two conditions of excitation.

To evaluate the effect of capacity loads in a more accurate manner, the actual effect of ampere turn relation between the armature and the field should be used in place of the modified relation as obtained directly from the short-circuit saturation curve. This can be done by separating the total effect of the armature current into armature reactance and armature demagnetization by the standard method; the real ratio of ampere turns will then be expressed by the component of demagnetization. For instance, in Fig. 7 of Mr. Smith's paper the short-circuit saturation curve (the intersection of the zero per cent power factor curve with the axis of field current) indicates that 1470 armature amperes corresponds to 220 field amperes. The true ratio, as expressed by the component o demagnetization, is approximately 145 field amperes. The same main flux and saturation will be produced by either 145 field amperes for 1470 armature amperes. The additional component of voltage for the same latter current, and due to the armature leakage fluxes will be approximately 2200 volts. These fluxes are largely in air paths and therefore, are practically independent of saturation. The terminal voltage of the generator under the conditions assumed, may be expressed as the voltage taken from the no-load saturation curve corresponding to $(I_f K + I_a)$ field amperes, plus $I_a \times x_a$,

where I_f = actual field current.

I_a = armature current.

x_a = armature leakage reactance.

K = relation between armature current and field current as expressed by the component of demagnetization.[2]

Fig. 1 gives the general construction for determining the voltage when a generator is connected to an open-circuiting transmission line or similar circuit with a high capacity effect. The

[1] A. I. E. E. JOURNAL, Vol. XLII, 1923, September, p. 894.

1. This constant K may be calculated directly from the design constants of a machine when these are available.

line characteristic curve is merely the relation between the terminal voltage and the leading reactive current in the external circuit. Curve (2) is curve (1) less the armature reactance drop. The intersection of (2) with no load saturation curve furnishes the point of operation required. The actual terminal voltage will be the point (P).

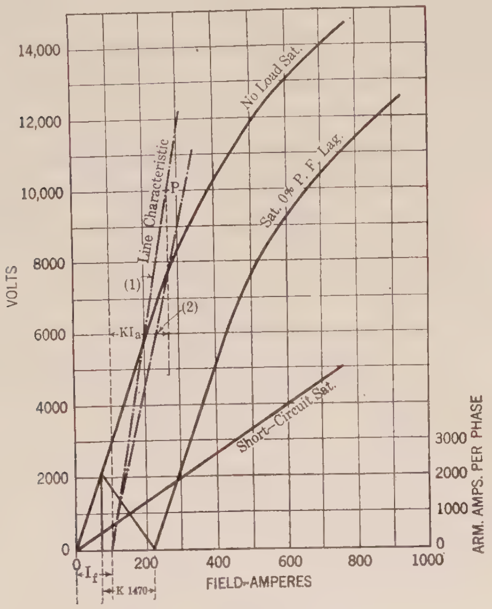


Fig. 1

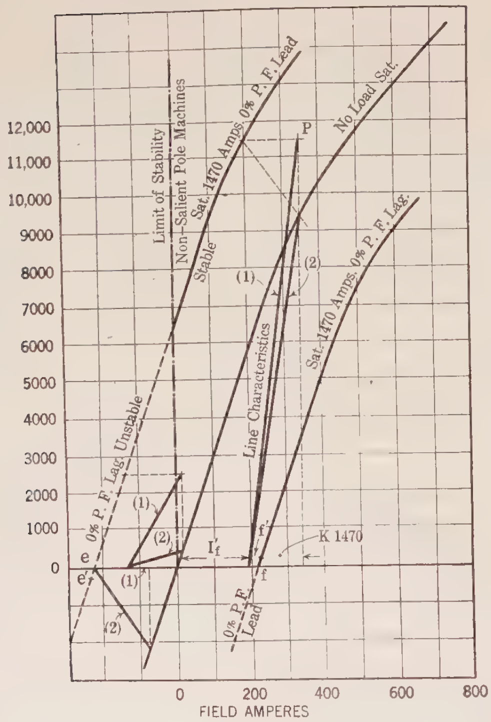


Fig. 2

Fig. 1 of Mr. Smith's paper gives two alternatives for the load saturation for zero per cent leading power factor at low voltages. Although of little practical importance, it may be of slight interest to investigate this point by means of the type of diagram described above. This diagram will be modified slightly to represent a condition of adjusting the d-c. excitation so that on varying the capacity of the external circuit, the armature current will be maintained constant. In Fig. 2, therefore, $K\ I_a$ will be constant while I_f will be assumed a variable, as well as the slope of the line characteristic curve. As the external capacity increases as indicated by the decrease slope of the line characteristic, the d-c. excitation must decrease and eventually reverse. When curve (2) coincides with the saturation curve, stability will cease so that with reversed excitation, the whole zero per cent power factor curve must be considered hypothetical, this, of couse, neglecting the effect of salient pole construction. Under this condition of instability, the voltage will naturally drop to zero, and build up in the opposite direction which is indicated by the relative positions of the two curves at the intersection. Assuming, however, that the voltage could be stabilized by some means, it will be seen that the load saturation curve must approach the point e, which represents the condition of an infinite capacity of the external circuit.

By rotating this diagram through 180 deg. it may be seen that the point e' may be considered as the equivalent of f' under the condition that the reverse excitation had been employed in taking the load saturation curve at zero per cent lagging power factor. It can, therefore, be considered that the points corresponding to short circuit and to an infinite capacity may approach either of the points e or f, depending upon the direction of excitation. In the case of the circuit of high capacity, however, the operating condition is absolutely unstable and not possible. This seems to represent the relations involved rather than the curve $d\,f$ of Mr. Smith's figure.

It might be suggested that there is probably only one method to actually obtain from test the values for the part of the curve which is unstable. By coupling two generators together so that their voltages are exactly in phase and consequently, that they can exchange no power by driving the machines from a separate source and properly adjusting their excitations the complete curve can be obtained for either condition of reactance or capacity, and moreover, the two curves will be continuous at the points e and f. The necessary stability is, of course, acquired through the mechanical interconnection of the two machines.

M. W. Smith: Although the criticism in the first paragraph of Mr. Shand's discussion may apply to the usual method, it is not applicable in this particular case. In determining the voltage obtained at the terminals of the generator when delivering 0 per cent, leading power factor current, the effect of both the armature re-action and armature reactance were taken into account. Furthermore, in Fig. 7, the two abscissas coordinates for "Armature Amperes" and "Field Amperes" are not interchangeable as apparently assumed by Mr. Shand, *i. e.*, they do not apply to the same curves. The abscissa for "Armature Amperes" applies only to curve five. Curve five, shows the values of terminal voltage, that will be obtained with various values of 0 per cent leading power factor current in the armature, with a constant d-c. excitation, and the effect of the armature reactance, as well as, the magnetizing effect of the armature, was included. The abscissa "Field Amperes" applies only to curves 1, 2, 3, and 4.

I wish to correct Mr. Shand's impression, that Fig. 1, gives two alternatives for the 0 per cent leading power factor curve at low voltage. As stated in the paper, if 0 per cent leading power factor could be maintained, the curve would extend to "e" at 0 voltage. It is further stated that it is not practicable to maintain 0 per cent power at low voltages on account of the increasing effect of the resistance in the circuit as the voltage is decreased and that in actual operation the machine would tend to follow the portion of the curve shown by $d. f.$ The portion $d. f.$ is, therefore, not a 0 per cent power factor curve, but represents the tendency of the machine to change over to points on higher leading and finally lagging power factor curves.

Both Mr. Shand and I agree that it is not practicable to operate generators at such low voltages and further discussion on this academic point is hardly justified.

EXPERIENCE WITH BEARINGS AND VIBRATION CONDITIONS OF LARGE HYDROELECTRIC UNITS[1]
(HARISBERGER),
WATERWHEEL CONSTRUCTION AND GOVERNING[2]
(BREED),
A STUDY OF IRREGULARITY OF REACTION IN FRANCIS TURBINES[3]
(WILKINS) DEL MONTE, CAL., OCTOBER 3, 1923

R. Treat: The device which was developed by Mr. Wilkins, appeals to me as being applicable to investigations of other similar problems. It appears to be a very simple, and it is hoped, reliable device which may be used for determining among other things, the pressures in the interior of oil circuit breakers at the time of opening the circuit and the stresses which are brought to bear upon bus insulators at times of short circuit.

R. L. Hearn: As one of the staff to install and put in operation the first two 55,000 h. p. units in the Queenston-Chippewa station, I had an opportunity to closely watch the operation of these units for some time after they were put in service. While we did not find the vibration in these units to be of such magnitude as to be dangerous, yet it was there to such a degree that it has made us give this problem consideration. We found the vibration to be worse at part gate and were inclined to consider the draft tube to be the prime cause due to the unstable condition of the water column in the draft tube under part load. Mr. Wilkins has shown in his paper that vibration can come from other sources.

I would like to ask Mr. Harisberger whether he has considered the affect of the draft tube on the vibration found in the units which he discusses in his paper. I have in mind the condition we found with two different types of draft tubes which were installed on the Queenston plant on two wheels of identical design. One draft tube was of the bent tube type, while the other was a Moody type draft tube. In comparing the vibration in these two units we found very little difference at full gate opening, but at part gate there was considerably more vibration with the bent tube than with the Moody tube. This difference we contributed to the design of the draft tube.

In many of the recent large installations of vertical type Francis turbines, the upper portion of the draft tube immediately adjacent to the runner has been constructed of cast iron and has been so designed that it can be removed, thus allowing the dismantling of the runner from the lower side of the machine.

In many cases vibration has caused the cast iron section of the draft tube to loosen from the turbine casing and I believe it is the consensus of opinion, that it is advisable to concrete in this section of the tube in order to absorb the vibration and thus protect the draft tube from being shaken loose.

In order that the work of investigating problems, such as we have just been discussing, might be more effectively carried on, we should develop a spirit of cooperation between the operating companies and the manufacturers. So often in the past, it has been the case that the manufacturer delivers his equipment and after acceptance by the purchaser obtains very little knowledge as to the performance of this equipment during its operating life.

E. R. Stauffacher: I would like to ask a question in regard to the interpretation of a curve, Fig. 4 of Mr. Wilkins' paper. In the later part of the notation underneath the figure the statement is made: "Hum apparent in both Power House and Pen Stock." By reference to the curve it can be seen that it is quite regular.

In Fig. 5, you will notice: "No apparent noise or vibration." By referring to the curve you can see that it is quite irregular. Am I right in interpreting these curves to mean that if the curve is regular, you have a source of danger, whereas, if it is irregular there is no danger?

Also, in reference to Mr. Harisberger's paper, as to the technique of determining the tone of the generator and the tone of the turbine, what method to determine pitch was used? Was it by means of a tuning fork, or just by the ear of this musical operator?

R. J. C. Wood: I would like to ask Mr. Wilkins whether any experiment was made by varying the speed of the machines slightly above and below the point at which he obtained these diagrams that he gives us, to see whether there was any resonance that might be in some portions of the casing or a water column of a length that would respond to certain frequencies, just as in some automobiles there is a certain speed at which the machine tries to vibrate itself to pieces, and below that speed you are comfortable, and also above it?

John Harisberger: In reply to the question as to how the tone was arrived at, this was done by the chief operator of this particular station by tuning in on a keyboard of a piano in the club house, which is near the power house, so the hum can be distinctly heard.

As to Mr. Hearn's question—Was anything done, or any attempt made to correct the difficulty by changing the draft tube? —No, this particular unit has a single-runner double discharge turbine with boiler riveted steel draft tubes similar to that of the two other units which have given no trouble. As the vibration occurs only at partial gate, in the neighborhood of 3/10 to 5/10 opening, and as it is rarely that the unit is operated at this gate opening, we did not think it necessary to go to much trouble or expense to correct the difficulty. In fact, we have not had any very definite information to work from until Mr. Wilkins' paper was presented, which seems to me gives us something well worth considering.

I would like to ask Mr. Wilkins if all the runners considered in his paper were Francis runners?

John Sturgess: At one period in our forward progress some particular problem seems to be right in the lime light and demands first attention, and during that period some of the other problems are side-tracked.

Now, I feel that is particularly true in the case of vibration, because many years contact with hydraulic turbines leaves the impression on me that this problem was relatively more fully solved several years ago than it is today. It is almost an example of partial retrogression.

In 1898 I spent three weeks on top of a hydraulic turbine at Niagara Falls, where the vibration was quite severe. At that date, 1898, hydraulic calculations and engineering were very inadequate. The wheel was designed for 2500 h. p., but it accidently developed 5000 h. p. The hand wheel for opening the gate was 18 in. diameter but before the gate could be opened it was necessary to strap to the hand wheel a 12-ft. beam with block and tackle at the outer end. While there was severe vibration in this unit, it was no worse, if as bad, as on some recent units, and I do not feel that this apparent retrogression is to be entirely accounted for by size of unit, or the head, for some of the new units were not materially different from the 1898 unit in respect to size or head. There has been recent discussion regarding synchrony between vanes and gates, but this was the subject-matter of discussion from ten to twenty years ago.

I would like to express a thought in regard to that part of Mr. Breed's paper illustrating the propeller type turbine, which, by the way I believe, if proper credit is to be given the original proponent, should be called the Kaplan turbine. It is obvious that the propeller type is nothing but the continuation to its logical conclusion of a process we have all gone through in developing high specific speed runners,—diminishing the inflow element and amplifying the axiflow element. It is easy to see that the complete elimination of the inflow element was the

1. Not yet published.
2. A. I. E. E. JOURNAL, 1923, Vol. XLII, December, p. 1261.
3. A. I. E. E. JOURNAL, 1923, Vol. XLII, November, p. 1141.

logical conclusion of this process. Yet it is called a "new" turbine.

Looking ahead, I expect to see for this type, before it is finally established as a standard, an entirely new type of gate developed. The swivel gate, while obviously correct in connection with the inflow turbine, is illogical when applied to the axiflow type.

L. A. Barnes: In regard to the 2.5 in. which Mr. Wilkins took off the runner. I assume he took that off in small amounts at a time. If he did not I would like to ask how he determined that amount? And, if he did take that off a little at a time I wonder if he could tell the success that he had in the successive cuts, that is, whether it was progressive or whether he arrived at it all at once.

R. Wilkins: In answer to Mr. Stauffacher, Curves No. 5 and No. 6 were taken on identical scroll cases with different runners and under the same head on the same pipeline. On No. 4 there was sufficient noise to make talking difficult, that is, the hum was so loud that you had to raise your voice to be understood in the power house; this gradually decreased up the pipeline yet you could hear the hum at the penstock. With the seventeen vane runner in an identical scroll case just beside it on the same pipeline, there was no noise that you could hear at all. There was no vibration that you could feel with your hand, yet the hydraulic pressures inside the pipeline were just as violent as those in the other unit. Both these, however, are considerably smaller than some of the other curves. Fig. 13, for instance, gives no hum; it is not regular enough to give a hum and it didn't give an actual noise, yet that unit vibrated so that we were afraid to run it for fear it would shake out the bearings; it was put under different conditions and it toned down as is shown in one of the other curves. I would not say that it entirely stopped but the pulsations were not audible or perceptible, that is, it wasn't dangerous. These pressure pulsations in pounds per square inch are quite high and we don't know just what they do; which is the reason for the investigation, because of the things that we were afraid they might do.

In answer to Mr. Wood's question: As far as the frequency of the system would permit, curves were taken from as low to as high as we could get with the load. Without load these pressure variations are light because there is little water entering the runner and as you decrease the speed you change the conditions under which that turbine operates at a different head and it depends on head and load conditions where it is the worst. If it vibrates at all it vibrates over all speeds, but there is a place where conditions are the worst and this depends on the design, principally, of the runner.

In answer to Mr. Harrisberger: All runners, as stated in the title of the paper, were Francis runners. In fact, all the runners we have on the system are Francis runners and the pressure that is built up in them depends on their design and the amount of clearance between them and the guide vanes. It is the way the water enters the runner that causes the variation in pressure. If there can be obtained between the runners, even on runners not correctly designed, sufficient clearance to equalize part of the pressure, vibration will be cut down. On the runners in which we tried to correct the vibration we cut back as far as we dared. On a runner 105 inches in diameter, we cut back about five inches, 2½ inches on each side.

R. J. C. Wood: I would like to know whether Mr. Wilkins noticed any relation between the shape of the guide vanes in these different units and the degree of vibration hum, or the oscillations?

R. Wilkins: The guide vanes, so far as we could determine, had very little effect on the water as it entered the runner. We tested practically all of the types of guide vanes available, and found no difference.

In answer to Mr. Barnes: The cuts taken off were as much as we possibly dared take off, but I don't think that we have enough off yet. There were no preliminary cuts and there have been none since. It is quite a job to disassemble a unit of that size and to make the cut at the same time; it is quite a loss to a power company to have to put out of service a unit of 35,000-kw. capacity on which such work is being done. We did the best we could at one guess.

HIGH-VOLTAGE INSULATION[1]

(HAYDEN AND STEINMETZ)

DEL MONTE, CAL., October, 4, 1923

R. W. Sorensen: My first point is in connection with the statement that we use our insulations under stresses which rarely exceed the breakdown voltage of air, though tests show a strength of 10 to 20 times that of air for many of the insulations used. This plea for a more strenuous use of insulating materials is interesting in the light of a request in another paper given this morning, in which the author recommends a decrease in the test voltage applied to transformers with one terminal grounded.

In Fig. 1 of the paper the curves show the interesting fact that a given potential will cause spark over between a point and a sphere for much greater spacing when the sphere is negative, than will be the case with the needle points negative and the sphere positive. The results shown in Fig. 3 have been duplicated by Messrs. Otis and Mendenhall, two students at California Institute of Technology as shown by the curves in Fig. 1

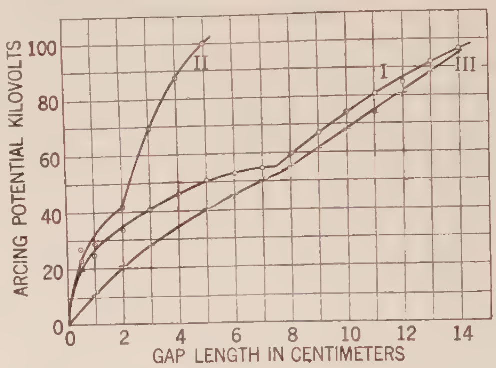


FIG. 1—ARCING POTENTIAL VS. GAP LENGTH

Between Needle and Sphere, 12.5 cm. dia.
Curve I—Direct Current. Sphere Negative
" II— " " " Positive
" III—Alternating Current, Maximum Values.

accompanying this discussion. In making these tests the high-voltage alternating current was rectified by means of a two-segment commutator driven by a two-pole synchronous motor.

The a-c. curve is very much like that obtained by Hayden and Steinmetz, but the d-c. curves differ in shape because of the pulsating current obtained with the commutator, whereas Hayden and Steinmetz had very steady current delivered by a four kenetron rectifier. An explanation of the dip in these curves would be very interesting.

In John S. Townsend's "Ionization of Gases by Collision" is found this statement "When the point is negative, the strong field is near the negative electrode, so that the potential required to produce a discharge is less than when the point is positive." Also in "Conduction of Electricity through Gases," 1906 edition, by J. J. Thompson on page 498 we find this statement "...........this minimum potential depends upon the sharpness of the point, the pressure and nature of the gas, and the sign of the electrification of the point, being less if the point is negatively than if it is positively electrified." Hence we have from these authorities statements which, at first reading, appear quite contrary to those given in this paper.

There is, however, some confusion as to the definition of the term "spark discharge," in the texts referred to the term does not seem to apply to an arc current and the voltage required

[1]A. I. E. E. JOURNAL, Vol. XLII, 1924, January, p. 36.

to cause it, but means the point at which a leak discharge only and not a complete arc over occurs between the electrodes. In fact in one treatise on the subject of ionization this definition appears: "Sparking potential may be defined as the potential which is required to maintain a very small current in the gas."

Dr. Millikan has explained the Hayden-Steinmetz results on the basis of the increased difficulty experienced in extending the ionization envelope with negative points, as compared to that phenomena for positive points, hence the required higher potentials for a breakdown over a given distance.

In discussing the mechanism of "thermal breakdown of dielectrics" the paper follows the work of Mr. Wagner as published in the JOURNAI for December 1922, but Wagner does not deduce the same law. Also some tests we have made in our laboratory do not conform the deduction that puncture voltage is proportional to the square root of the thickness of dielectric.

To emphasize "time lag" is indeed worth while as our experience shows it an important factor in making an analysis of voltage stresses on insulations, and indicates that an intensive study should be made of the laws which govern it. It may be of interest to note here that in testing thousands of porcelain insulators I have found that very few which stand a potential test at minimum arc over voltage for fifteen seconds, fail when the potential is applied for a longer time. In testing apparatus insulated with organic insulating materials very often potentials apparently harmless when applied for short periods will cause breakdown when applied for longer periods of time.

At the bottom of the last page: "It follows from this, that the conducting particles or carriers, which carry the disruptive discharge in air at atmospheric pressure, are positively charged, that is, they may be the positive ions, but cannot be the negative electrons."

If an atom is ionized and you have your positive ions turned loose what becomes of the negative ions, where do they go?

Then follows: "At atmospheric pressure the voltage required for ionic conduction, that is, disruptive discharge, is much lower than the voltage required for electronic conduction." This is explained further on in the paper. If you have a perfect vacuum, as stated, how would you have the pure electronic conduction? I presume tubes in which there are heated filaments have been used.

C. P. Steinmetz: The paper deals with a subject which has assumed, in the last year, a still greater importance than it had before, that is, the problem of high-voltage insulation and mechanical breakdowns.

This is such a vast field and so much work has and is being done, and can be done, that the paper must necessarily be only a general part of the preliminary announcement of the results and investigations, with a more complete record of results to be announced at some future occasion.

There is, however, one feature which begins to get clear, namely, that our conception of insulation and of breakdown of insulation again begins to change and to be subjected to multiplication. To members in the early days, insulation was merely a boundary bar. We knew, by experience, that a tenth of an inch of insulation of a conductor would protect it against 2300 volts. Then, when it came to higher voltages we realized that there is something occurring within the boundary bar, of importance, and it is not merely the material, but there is a dielectric field with potential radius and other things within the boundary bars which require consideration and study, and which we are studying.

Now, it seems that our views are just beginning again to get a multiplication with respect to at least the failure of insulation and the mechanism of breakdowns. It seems to be clear that the mechanism of breakdowns, under the failure of insulation on high voltage is a phenomena of instability. In other words, it is not that insulation fails, that dielectric breaks down, when electric stresses are beyond limits and value, but it is said that under conditions very much lower than those gradients in lightning conditions of instability occur which gradually brings about the multiplication and changes leading ultimately to a breakdown of insulation. It is, therefore, a condition of instability of constants of material which instability brings about, largely upon lesser changes, which leads either to destruction or breakdown. Therefore, the mere reduction or stress on the insulation is not a factor which saves breakdowns, but that the new problem of insulation seems to assume the shape of arranging of designs in the dielectric field of insulation, so as to get the condition of stability and not instability. That is the future which seems to impress itself upon us. The more we study the problems of insulation we find that it is not existing stresses that cause this, but largely it is the result of stability, or instability.

Now, that is not only true in solids, but probably in the air. In this respect we could point out the same idea that the discharge makes its own gradient. Now, you have the same conception there, that it is the discharge which is taking place in the dielectric field about conditions which are unstable. We all know that if we had 2,000,000 volts spread over, I don't know how many thousand inches, there could be a gradient that would be so low there would be no puncture and for that discharge under such conditions. By the discharge making its own gradient there would be produced a dielectric condition of instability which would finally lead to self-destruction.

METHODS OF VOLTAGE CONTROL OF LONG HIGH-VOLTAGE LINES BY THE USE OF SYNCHRONOUS CONDENSERS[1] (KOONTZ),

DEL MONTE, CAL., OCTOBER 4, 1923

A. W. Copley: In amplification of Mr. Koontz's paper and carrying out the thought a little farther, it may be pointed out that there is a very definite power limit on a transmission line on which the values of generator and receiver voltage are fixed. The addition of synchronous condenser capacity beyond a certain limit does no good as far as increasing the capacity of the line is concerned. For instance, on a 200-mile line with 200 kv. maintained at both ends, the addition of synchronous condenser capacity beyond the point which allows a load of about 220,000 kw. at the receiver end, does not increase the capacity for transmitting power. The power limit of such a line being in the neighborhood of 220,000 kw., it can be seen that, at least on projected lines, the limit is being approached. It is, however, possible to increase the power limit of the line by making, in effect, two lines in series. For instance, on a 400-mile line, with synchronous condenser capacity at the receiver end, the limit of capacity is around 120,000 or 125,000 kw. By breaking the line in two parts of 200 miles each, the power limit of the upper end of the line is about 220,000 kw. and with that power delivered to the middle of the line, the balance of it again has the capacity of 220,000 kw. minus the losses, which bring the delivered power down to about 200,000 kw. That is, by the introduction of condenser capacity in the middle as well as at the receiver end, the line capacity is increased from 125,000 to 200,000 kw.

One other point mentioned by Mr. Koontz which is of much importance, is the method used for the control of the exciter voltage at times when lagging current is being taken by the generator or condenser. When the line is being charged and no load being carried, the condenser must be operated with a very light field. The same holds true of the generator field under the same conditions. With the ordinary generator voltage regulator, the voltage across the generator or condenser field can be controlled only down to about the residual voltage of the exciter. By cutting resistance directly in the field of the condenser or generator the voltage across the field can be reduced still further and it is now possible to do this automatically

[1]A. I. E. E. JOURNAL, Vol. XLII, 1923, December, p. 1255.

by means of a face plate regulator which is operated as an auxiliary to the usual generator voltage regulator. Such a regulator has been applied on the generators of the Big Creek No. 3 Plant of the Southern California Edison Company. It allows the lowering of the voltage acrcss the generator field to something like ten per cent of the residual voltage of the exciter and thus there is obtained a considerable increase in the lagging current capacity of the machines while under the control of the regulator.

R. J. C. Wood: I didn't quite understand what Mr. Koontz said about the generator voltage being low under certain conditions of operation, when the load was low. We have made calculations on the Big Creek System 250 miles long—that line, with 100,000 kw. per circuit, transmitted from Big Creek No. 3 plant, including the effects of the transformers on the line, which take certain magnetizing currents. It developes that the variation of the voltage on the generator will be very slight between zero load and full load. As I remember the figures the 11,000-volt machine requires slightly under 11,000 volts at zero load and in the neighborhood of 11,500 or 11,600 at full load. So, the variation at the generator is slight and the demands on the regulator will not be heavy.

About what Mr. Copley said relative to putting synchronous condensers in the middle of the line, that, of course, gives you a new lease of life. You get power at the end of the first section of the line at a certain voltage and at power factor desired and start all over again in the next section of the line. The method has its limitations and would not be used on a comparatively short line.

The calculations for the Big Creek 250-mile line indicated that there was no advantage in putting condensers in the middle of that line. The installations of a synchronous condenser at the middle point causes a loss of, roughly speaking, one-half of its capacity. A great many of these calculations are often made for the line only and the effects of transformers are not taken into consideration. This should be done, as illustrated by a test we made when we were first getting ready to energize the line at 220 kv. One of the preliminary steps was to test the transformers and equipment of the Big Creek No. 8 Plant. We had generators and transformers at the Big Creek No. 8 Plant, a 220-kv. line about 105 miles in length, from Big. Creek No. 8 to Vestal, and in addition auto transformers at Big Creek No. 1, No. 2 and also at Vestal, if I remember rightly. The result was that we got about 600 amperes on the generator at considerably less than full voltage and when we were up to full voltage on the line only 300 amperes, on account of the large amount of magnetizing current taken by the transformers on the line, so that you have a very good regulator in the magnetizing current of transformers; if the voltage tends to increase greatly on account of loss of load, the magnetizing current will increase rapidly and neutralize the charging current on the line and prevent excessive voltages. Magnetizing current may be taken at about 4 per cent of full-load current at normal voltage; at 110 per cent voltage it will be about 12 per cent, and at higher voltage—the manufacturers conceal what it is going to be. They need not conceal it; for our particular purpose it is a good thing to have.

J. A. Koontz: The statement, that there is a wide variation in voltage at the generating station, should refer to the exciter voltage. The generating voltage usually only varies some 8 or 10 per cent depending on how the lines are operated. On the lines of the Great Western Power system, this variation amounts to 10 per cent. The impression I intended to convey was that synchronous condensers have to operate over a rather wide range of terminal voltage, particularly when they are operated from high-reactance transformer windings which supply no other load. The condensers require minimum field excitation when the machine is supplying the minimum terminal voltage, and maximum field excitation at maximum terminal voltage, hence extreme exciter voltage variation. I have a case in mind where the condensers deliver only 9800 volts at minimum field and 12,200 volts under maximum field conditions. It is this change in machine terminal voltage, together with the magnetizing or de-magnetizing effect of the armature, which necessitates extreme field ranges and makes difficult regulator operation.

A MODERN MARINE INSTALLATION

The M. S. *Cubore*, first cargo ship to be equipped with the new type Bethelehem oil engine and a full complement of automatic magnetic control deck machinery, was given her sea trials February 8, a day's trip outside of Baltimore. Because of the wide interest in the unique equipment of this ship, many persons prominent in naval architecture and shipbuilding, including representatives of the Emergency Fleet Corporation, made the trip.

The *Cubore*, 450 feet long and with a dead weight tonnage of 10,500, is owned by the Ore Steamship Corporation, a subsidiary of the Bethlehem Steel Company, and will be used to carry ore to Sparrows Point, Baltimore. The oil engine was originally installed in the *Cubore* late in 1920 and, with the exception of a tie-up for modifications to auxiliaries and engine, has been in steady operation since that time. The engine modifications are the result of the 2½ years of sea experience.

The outstanding points of interest are not only the new type Bethlehem oil engine, but also the auxiliaries, all of which are electrically operated by General Electric marine type motors and control. Steam is used for heating purposes only. Three 100-kw. direct-current generators, driven by three Diesel engines, supply the necessary power for the auxiliaries, including a 75-h. p. motor for the windlass, eight 50-h. p. motors for the mooring winches, six 25-h. p. motors for the cargo winches, the lighting system and all engine room auxiliaries. One generator only is required to supply this power except when the ship is in port, loading or discharging cargo, when two generators handle the load.

The engine room equipment is of the most modern type. The pumps, mainly of the centrifugal or rotary type, depending on the service, and the auxiliary air compressors, are operated by marine type, enclosed ventilated motors.

A new feature among the deck auxiliary equipment is the automatic mooring winches, designed to perform a service covered by no other electric winch on the market today. These are so constructed that, without manual attention, mooring lines are payed out and taken in as the boat is moved about by sea swells and other conditions. The lines are thus automatically kept taut at all times.

The cargo winches, ordinarily used to open and close hatch covers, are fitted to handle cargo when the occasion demands. To meet this service, the control on the *Cubore* is of the latest magnetic type now in universal use.

The use of magnetic control winches will result in a 15 to 20 per cent saving in time of handling cargo.

Fortieth Anniversary Celebration of the A. I. E. E.

Addresses in Philadelphia by Three Charter Members with a Résumé of Electrical Engineering Progress

The 40th anniversary of the Institute was fittingly celebrated during the Philadelphia Midwinter Convention at a meeting held Monday evening, February 4th, at which President Harris J. Ryan presided. Addresses were delivered by Elmer J. Sperry, T. Commerford Martin and Elihu Thomson, all charter members, and by John J. Carty, past-president of the Institute.

President Ryan presided, and in opening the meeting said:

"The hour is one in which we all rejoice to have come to Philadelphia because it was the home city of the first American electrician, the man of whom we all know, and who enabled us to understand very clearly and for the first time in this world what is lightning. From what he did for us in that way, we have had many an inspiration of the most valuable sort to carry us forward to know many of the other things and what they are and why they are.

"Through all this came the inspiration on the part of a group of men forty years ago to give us this, our American Institute of Electrical Engineers. We have assembled to do honor to those men tonight, to remember the beautiful and valuable organization that they gave us through their vision and their enthusiasm as young men. We are glad to know and to be together to rejoice over the considerable number that have lived through the entire generation, the lifetime, the time of one generation of active business at all events.

"The first man I am going to call up who joined with others to give us our Institute in 1884 is the youngest charter member who had at this same time to come the greatest distance for the organization meeting. He came all the way from Chicago to New York. Mr. Elmer A. Sperry."

Address of Mr. Sperry

I feel that the Institute is very young; it is really the youngest member of our technical bodies. You remember the Civils were formed in '52; then the Miners came along some time in '77; then the Mechanicals were organized about 1880, and then this body came into existence in 1884.

These things, of course, don't happen, and while the pioneer is doubly, in his own way, always having a hard time, when he starts, or he imagines he does, then when he comes along later to tell about it, tell how it did all happen to happen, he rather gets in the way, and the young people with the forward look and on their toes as the members of this Institute always have been, say, "Well, make it brief." So I will try to make my part of it brief.

There were two groups that had their young enthusiasm and were willing to make some sacrifice to see if we could not have an American Institute of Electrical Engineers. In the Western Group—I was living in Chicago—we had about eight people. Our keynote was that England had had the Institution of Electrical Engineers some four or five years. They had had, it is true, that marvelous body, the Society of Civil Engineers, but we in America had matched that in 1852, as I stated before, but they were definitely ahead of us, and it was a going concern, and the papers that they heard and the scientific matter that they put forth at that time were an envy to us all here. In the Western group we felt as though something should be done. We cast about and found that there was an equally enthusiastic group in the East, but we in the West were all young fellows.

In the East it was quite different. We found a man who was then forty-six years old, who was really the leader, and do you know that we have the great and unusual honor of having him here tonight? It was due to Nathaniel S. Keith, sitting yonder, that the matter was thoroughly stirred up in the East, and finally a petition was circulated, which never got West, by the way, containing the names of those who were willing and anxious to see such a society formed.

That body got together on April 15th in the rooms of the Civils. I have one or two pictures which I have had taken showing how that building looks today and about how it looked when we went up the steps that night, May 13, just one month later.

The meeting in April succeeded in getting ten more names on this list of "Come, let us have one," and the time of the inaugural meeting was then settled upon as the next month, Tuesday, May 13, and then we felt as though we had in sight our Institute, our dream, and so there were five of us in Chicago who were going to start. Two dropped out and finally two more, and it was wished on me to come down and do my part in swinging my arms and seeing to it that the Institute was put on the map.

So I came, arriving in New York as I remember, at ten o'clock in the morning and proceeding directly to

the Astor Library and working there all day. I don't suppose any of you know that the Astor Library never had any artificial illumination. They found that gas ruined the books, so they couldn't have gas, and Edison hadn't come on the map yet, so they had no artificial illumination and I was turned out at early candle light to get my dinner and proceed to the rooms of the Civils, 127 East 23d Street, away uptown, to attend the inaugural meeting.

Getting my dinner early in that way, I happened to be the first, if not the very first, up in the rooms. As I remember, I waited quite a little time and the second man to appear was Dr. Keith, come to see his child born. I complained to Dr. Keith. I said, "How is it you fellows in the East do so much talking? Do you really do anything?"

He calmed me down and told me to wait, that the people in the East possibly would be a little late, but they would be right there, which they were. Some forty of us gathered there in the rooms.

One little incident in the first meeting was that we had Mr. Edison there, and that was a long time before we knew it was impossible to get him to speak. So T. Commerford Martin, and some of the others concocted a scheme to head him off from going upstairs, and we would rush him from below, and when he got halfway up, we would all say, "Speech." That was before we knew he would rather climb under the table, which he did in '93, rather than make a speech. But we totally failed to elicit anything from Thomas A., although he was the greatest electrician of the time. That was the word that was used, as I will quote presently, and you will notice how different our nomenclature is at the present time from what it was then.

He, however, made his bow, and as you may not know, he was looked upon as the great successful electrician. I must use the terms of that time. He had not long previous to that time sold to the telegraphic interests his quadruplex and it was noised around that he had received four hundred thousand dollars for it, and that was a stupendous urge to the young imagination. He was a young man at that time, as of course, you know. But some of the observations that might be made with regard to the personnel might be stated as indicated by the fact that we elected Norvin Green as our first President.

He was the President of the Western Union Telegraph Company. That was the system of electrical engineering in that time, and a cross-section of the activities would show wonderful progress on the part of the Telegraph Company, and, of course, a wonderful steady progress which just before that had been made by the Telegraph Company by getting four messages over the line, something that Dr. Jewett now smiles at. It is so easy now to put a great many telephone and telegraph messages over the same wire.

In those years the membership was to be as follows: (this is from the *Electrical Review*). The electricians must have been very active in those years. Here were three live journals reporting this meeting. The description of who could become members and who could not is rather amusing.

"Members are those who may justly be called electricians because of professional employment and general recognition as such. All others are to be associate members, persons who are connected with electrical matters directly or indirectly, but not ranked as electricians. Thus the president of an electrical company might or might not be entitled to full membership, but there would be no question of the professional electrician, employed by such a company."

Our light at that time was nearly all arc lights. Edison, just a year and a half before in September, had just set into operation the Pearl Street Station, and divided electricity, which our English savants said couldn't be done, but he just used horse sense. He said, "The gas mains go down the street and are tapped for individual residences. Let's do the same thing with electricity," and he did it. He put it over, and that is one of the reasons we are here tonight, because that was so wonderfully successful. He had started the Edison Company then. The Brush Electric Company was our oldest company, dealing entirely with arc-lights. Streets were illuminated and municipal companies had been formed, but just a little before that time there had been a junction formed between our redoubtable Elihu Thomson, whom you will hear from here tonight, and the great C. A. Coffin, whose dream was the General Electric Company. Few people live to see their dreams blossom and come into full fruition as Dr. Thomson and Mr. Coffin have. All honor to them both!

It was about this time that Edison saw fit to curtail the great long legs of his generator and find that spindling legs were out of style, and they could be shorter and plumper and still do the same work, and have a higher efficiency, as I remember.

But Edison, in those days, wouldn't have anything to do with the conception that the whole potential of a great system could possibly behave so ridiculously as to change its mind as to the direction in which the potential was impressed upon that system, especially as frequently as one hundred twentieth of a second. That was unthinkable! It was the marvelous conception and intuition, almost, of Elihu Thomson that said, "Yes, we will take that whole network and change our minds every one hundred-twentieth of a second," or as I remember, we had 125 cycles per second, and that was the means of distribution over the territories.

It was the initiation and bringing forward of the alternating current system that made the great expansion of the Thomson-Houston Company, which transcended upon us. I was swinging my arms in Chicago. I had my share of the trade in arc-lighting, and we had a great many cities in the West, Sperry towns, we called them, but it wasn't very long before the alter-

nating current and its capacity to give us live distribution of light in small units came along, and became a tremendous competitor, and finally won out as we all know.

The Hochhausen Company was also in operation at that time and the Western, as you remember. When I got to Chicago I found one plant running and that was the Western plant at the Grand Pacific Hotel. The Brush Company had been in two or three years before the rest of us and they had a number of towns in the East and West lighted by arc-lights.

One of the great troubles that we immediately discovered when we commenced to put in arc illumination with these municipal plants in the towns, was the terrific interference with the telephone. The telephones in those times, as you remember, were one wire. Nobody was making any money. They were poor, struggling concerns in little and big towns, as was our own company, and to think of having two wires for one conversation at that time was impossible, and it was less than a year until the National Electric Light Association was formed by a convention called together of all the arc-light producers in America, to see what on earth we could do to get rid of the very great interference with the telephone company.

The town council would make us put our poles on one side, and the telephone people on the other side, and yet whenever we started our plants, and especially when the Thomson-Houston Company with its sinful three coils came in, the induction was something fierce and every telephone went bad.

We claimed that the telephone wasn't very much account and we couldn't use it when it stormed anyhow and we couldn't use it across any large intervening space, and they claimed that our lights hissed and were too strong and didn't amount to anything anyway. There we were.

At the time of this convention, (allow me a word; I told this tonight at dinner, but it is really worth repeating), an envoy from the great Theodore N. Vail rose up in the meeting and said, "I represent Mr. Vail of Boston. He sent his regrets that he couldn't be present in person."

Then he took out of his pocket a little document which showed the greatness of Theodore N. Vail at that early date. The document went on to say, "It is a thing that we will overcome, this interference of the service one with the other. All we have to do is be patient with one another. Be patient and you will find us ready to do everything we can to help the cause along."

Think of the beautiful spirit! There is in this room, and is to speak from this platform, the boy that solved that problem within that year, General J. J. Carty. He found such wonderful effects by twisting two wires together and using the two wires for conversation that it spread like wildfire. Before the year was over, our poor telephone companies who weren't making any money adopted the system and our troubles were over. So it was the telephone company after all that did it. We swung our arms and found much fault, but did very little, and it was through the wonderful initiative of Vail and his great organization that that thing was straightened out.

Now, it is a strange thing that this last winter the meeting of this very Society had as its keynote the very self-same thing, and the cycle is about forty years. I should like to be on earth and know what comes around forty years hence.

Mr. Sperry then showed several views of the first home and the first secretary of the Institute.

PRESIDENT RYAN: The next speaker, who on the occasion referred to by Mr. Sperry could not induce Mr. Edison to speak, did succeed in making him speak. We members of the American Institute of Electrical Engineers as it exists today, have all a great inheritance from him. He did a wonderful work in the early days of the Institute in helping the organization to get down to a plan of running its meetings, conducting discussions, in reporting the same, and in broadcasting the results of these activities. He is one of the Past Presidents of the Institute, one of the early Presidents, Mr. T. Commerford Martin.

ADDRESS OF MR. MARTIN

Fortunately it is not like deciphering palimpsests to get down to the fundamental data concerning the early history of the American Institute of Electrical Engineers. The inmost rings of its growth are still very close to the bark. While not extant in lavish profusion, the printed record may still be found on many library shelves, and stray beams of human memory still flicker over the archives.

The creation of the Institute coincided happily with two other notable occurrences in electrical development on this Continent. It was a corollary of both; while all three events may be definitely traced and attributed to that ancient splendid exemplar of scientific leadership, the Institute so well named after out great pioneer, the Immortal Franklin. Dating from the Centennial Exposition of 1876 with its memorable exhibits such as the Bell telephone, the Edison telegraphic inventions, and the Wallace-Farmer arcs, there had followed a period of electrotechnical advance unparalleled before or since. The Franklin Institute in 1883—with the same prescience that has just led it to bring over J. J. Thomson to lecture on the electron—felt that the times were highly propitious for the First American Electrical Exhibition, to excell those of London and Paris. The Franklin Institute might well have waited for the full decade after 1876 to elapse; but it is not in the nature of Philadelphia to wait when it wants anything whole heartedly. Moreover, the British Association for the Advancement of Science was meeting in Montreal in 1884 and would bring a whole swarm of European scientists and physicists across the Atlantic.

These could be lured Southward from Canada to the projected Electrical Congress the same year, timed to synchronize with the Exhibition; while they would not easily retrace their steps later, if the opportunity to enroll them were pretermitted for a year or more.

Hence, with two such compelling factors as to 1884, the Exhibition and the Congress, it was indeed, inevitable that the foundation of the A. I. E. E. should occur in that year. Possibly there was some propaganda traceable to Philadelphia and the Institute, but it was, if so, wholly desirable and necessary, everybody felt, that not only to greet fraternally the visitors from abroad, but for the sake of the art itself, there should now be a national electrical engineering society, before any time was lost. Crystallizing with energy and enthusiasm, all the ideas and impulses finding vague indefinite expression, Dr. Nathaniel S. Keith published in April, 1884, his memorable circular reprinted on the very first page of Vol. I of the Transactions of that year. That circular, prepared and issued by himself and colleagues, among whom the present writer is proud to be included, was submitted to the leaders in the electrical field in various parts of the country, with separate name sheets that could afterwards be assembled and thus permitted simultaneous canvassing even in quarters that in those highly-strung days were avowedly hostile and antagonistic to each other, but all of which recognized the common need of a central technical authority without bias. It was convincing also to be able to point to the American Society of Civil Engineers founded in 1852; the American Institute of Mining Engineers, in 1871; the American Society of Mechanialc Engineers, in 1880, "which have been so prosperous and of such great advantage to their members." Besides that, none of these bodies made any provisions for "electricals" as such, and even if Sir William Thomson said that "electricals" were "nine-tenths mechanical," that would perhaps not always be true; and it needed more than that to thwart the sound normal American instinct to organize another Society whenever a decent chance offers.

All went well. The Roster lists were carried upstairs and downstairs and into the magnate's chamber, and failed not once of the signature sought. Advice and help came freely from the Franklin Institute, never out of touch, and at last on a dirty, miserably wet night, Tuesday, April 15, 1884, the first meeting was held for organization, with an excellent attendance. Preliminary work had been done carefully, and the stage was quickly set for Tuesday, May 13, when the Committee on Organization reported not only a complete slate of proposed officers, but a brief Constitution. Both were unanimously adopted and can be found fully set forth in Volume I of the A. I. E. E. TRANSACTIONS now an exceedingly scarce document, but still available bound up usually with the three subsequent Volumes. The first Constitution, admirably brief, was adequate for the times. It has been frequently enlarged and modified, but Constitutional amendments are not always and wholly admirable.

The rendezvous for all those meetings in 1884 and others, for a year or two later, was the stately old home of the Civil Engineers, 127 East 23rd Street, where its courteous and efficient Secretary John Bogart, later State Engineer and consulting engineer for Niagara Power development extended a most cordial welcome. Then and later, until the splendid gift of Dr. Carnegie came and the United Engineering Building was erected on West 39th Street, the various Societies occupied others like it—fine old typical New York dwellings. Indeed, for the Electricals, a serious effort was soon put forth to secure the charming old home of Morse on West Twenty-second street, just off Fifth Avenue; and to make it possible, the writer offered to occupy with his family one or two of its upper floors for a rental that would guarantee the investment. But negotiations with the owners, the Bourne family, fell through on the score of price. The Twenty-third street region was then at a high crest of values, and was marked for commercial devastation. The Civil Engineer rooms were, moreover, admirable for their purposes, and there were no strings to the welcome except an injunction from Bogart to keep down the gas bills—talk after 11 wasn't worth it.

The Institute was fortunate in its first President, Dr. Norvin Green, a towering, swarthy Southerner, who had long before ridden the circuits as a rural doctor with pills and plasters in his saddle bags, and who out of the ruck of provincial presidencies of subordinate telegraph companies had lifted himself to well won supremacy as head of the Western Union Telegraph Company, with headquarters in New York. He was leadership personified, and out of scant leisure, he gave the best that was in him to the affairs of the tiny Institute, in whose opportunity, necessity and mission he had a profound belief. He was always available for Executive and other Committee meetings, with prompt suggestions for diplomatic and practical disposal of problems. But he was much more than a formal President. His warm Southern blood, like his sympathies, ran swiftly, and he loved to temper debate with anecdote. Pat to the occasion or incident, rollicking good stories would come in delightful succession from their endless store of a born raconteur; and even if it was maybe "at long interval," his board meetings might well be compared with those of Lincoln and his cabinet. It was, indeed, easy for Dr. Green to set an example on attendance, for he lived in cosy apartments quite nearby, where hospitality was more than the proffer of a dry cracker.

Equally fortunate was the Institute in its first Secretary, Dr. Nathaniel S. Keith, who still lives, unquenched, and can tell his own story, but who deserves the tribute of his colleague and successor. A master of his own mining profession, he was a skilled and accomplished electrical engineer, which then meant more

than plain electrician. He was studiously familiar with foreign electrical literature, from which he translated one of the first and one of the best German treatises on dynamo electric machinery, an art then obscure and occult. He was a brilliant technical journalist, and entirely competent in the politic arts and graces of secretaryship. All he lacked just then was the gift of continuity, for no sooner had he seen his hopes and ideals realized in the foundation of the Institution than he went to the furthest West, to stay for years, to grow up with it and electricity, and become the first American to build any kind of electrical machinery on the Pacific Coast. He left as a timid successor and probationer the present writer, his equal only in faith as to that future of the A. I. E. E. which they had forecast with buoyant optimism.

Other honored names might well be mentioned here and dwelt on, of those who at the very start gave their highest endeavor to the fostering and upbuilding of the Institute—in Philadelphia, Carl Hering, E. J. Houston, W. D. Marks; in New York, C. O. Mailloux, Joseph Wetzler, "Steve" Field, nephew of Cyrus, Francis Jones, George Hamilton—in the East, Thomas D. Lockwood; in the West, Elmer T. Sperry—but it must suffice to signalize Franklin L. Pope, the second President, and a Vice-President for 1874-5. Not long before, he and Edison together had in telegraphic journals announced themselves to the world as "electrical engineers;" and diligent search has failed to encover any earlier attribution of that honored title for the new profession and the new practitioner for whose legitimate working spheres no limits have ever yet been found in the electrical era *now* beginning. Pope's brief Presidential valedictory, in May 1887, was characteristic of his broad outlook, and not less typical of his simplicity and modesty in omitting any reference to the highly useful work he had done as organizer and administrator. A scholar and student, author of technical textbooks, he came from that wonderful group of well-trained, well equipped telegraphers whose scientific class room was the noisy- key-clattering office of a commercial company but had there learned the secrets whose mastery carried them to leadership in all our later fields of marvellous electrical achievement. Ponderous in movement, slow in speech, deliberate in action, pontifical in dignity, Pope was far more the conventional Englishman than he was the born Yankee—until some cause like the Institute moved him to unsuspected depths, and he became transfigured with the vision glorious. Never was the chair of the Institute more worthily filled by an "electrical engineer" than by him who first, in unwitting prophecy, gave himself the accolade of that appelation.

Reference has been made to the hospitable halls of the "Civils" as the home of the Electricals, and rallying place they were for a few years. But fortunately, the Institute officers decided early that an annual meeting would not suffice, so the young Society made a practice of getting together at frequent intervals for papers and discussions—in New York, of course, as only there could a good membership attendance then be registered. The writer's report as Secretary—the first ever made to the Institute, dated May, 1885—stated proudly that it then had already 279 members and associates; but they were "in all parts of the country." It has been interesting to see resumed in the last year or two the local New York meetings that marked the initial stage of Institute work, although to insure a good attendance and be comprehensive, topics are now chosen that will interest local members of all the four national engineering societies. The writer has enjoyed lately several excellent meetings of this character. This offsets also the centrifugal tendency which has scattered such members so widely over the huge metropolitan territory, in which one can now hardly ever go home to dinner and get back for the meeting. Forty years ago, most members lived in close proximity to the meeting hall. It was thus found desirable and feasible to get together every few months in "special meetings" when, no matter what the topic, a very large percentage of the local members turned out. Especially was this the case when the meeting was held at some restaurant, with preliminary dinner, and it is curious to note as a sign of local changed times and conditions that some of those meetings were held as far down town even as Broad Street, or else Broadway South of City Hall. One very far northern rallying point was a famous restaurant cafe, Martinelli's, on Fifth Avenue, south of Madison Square. In his Presidential address, Mr. Pope said of the "Special" meetings in his seat that they "have proved to be most successful and enjoyable reunions and have certainly done much to strengthen the Institute."

But all that fades into relative insignificance before the great functions with which in Philadelphia in 1884 the Institute was so closely associated and to promote which it had, on its creation, joined hands most promptly with the Franklin Institute. The first of these was the Electrical Congress of 1884, the first held on the American Continent. It was a most successful affair, marked by large attendance from abroad—notably such men as Sir William Thomson and W. H. Preece—by brilliant and animated debates on the definition and establishment of fundamental electrical units. Even at this remove one can recall vividly the masterly presentation by Prof. Harry Rowland of his great work in the determination of the Ohm. The good results of this first American Congress made it easy even in the panic year of 1893, to bring together, again with distinguished visitors from abroad, notably Von Helmholtz, the Electrical Congress in Chicago. This again was accompanied by a splendid electrical exhibit as part of the Columbian World's Fair.

But as the Institute is tenting and camping tonight on the old battlefield of 1884 here in Philadelphia, it

may forgive—even expect—a casual peep at its own modest little performance of September and October that year. The Exhibition Building was the spacious old West Philadelphia depot of the Pennsylvania Railroad Company. There the Franklin Institute had generously placed two large rooms at the disposal of Dr. Keith. They were fitted up comfortably by him and were open to members and guests from September 2 until October 11. As a great many members were actively connected with the numerous fine exhibits of electrical and steam apparatus, those Institute headquarters were immensely useful and popular. Everybody met there every day. On October 7 and 8, the first convention ever held by the Institute was conducted in the rooms and at the fine old Continental Hotel—the Bellevue-Stratford of its day as to splendor and comfort—but fortunately not as to prices. The report of that 1884 Philadelphia Convention constitutes the bulk of Volume I of A. I. E. E. TRANSACTIONS—traversing such diversified arts as to wireless, underground wires, multiplex telegraphy, earth return, carbon filaments and the incandescent lamp, batteries and electrochemistry, electric roads and subways, the Edison vacuum bulb effect from whose study such extraordinary results in electricity and physics have followed, and some of the first explorations of the dynamo. It was and is all in harmonious precedence and prophecy of such a program as that of this week for the Twelfth Midwinter Convention.

The Exhibition, the Congress and the Convention were soon followed by a most valuable series of Jury Reports issued by the Franklin Institute, on the Exhibits, and to the preparation of which a large number of A. I. E. E. members contributed in various important ways, notably such experts as Prof. E. J. Houston and the indefatigable original "man from Missouri," Dr. Carl Hering. Nor was that all in the way of electrical literature springing from the events of 1884. Dr. Houston, confirmed and inveterate pedagogue, issued during the Exhibition an admirable little series of electrical leaflets. Their matter and manner were cleverly mimicked and plagiarized in a rival series issued by the Mystic Order of Kazoos. Frank and open confession may here and now be made that the cosy rooms of the Institute were just as convenient for their surreptitious writing and publication, as for the preparation of Volume I of the TRANSACTIONS of 1884, then undertaken by the writer with valuable Keith collaboration; soon to be followed by Volumes 2, 3 and 4, from the hands of Secretary Ralph Pope, elected in 1885, author of the excellent first A. I. E. E. YEAR BOOK. Some of the quips and jokes of the priceless Kazoo leaflets were part of electrical haus spreche for many years thereafter. Almost up to the moment when before the Institute a score of years ago, Steinmetz enunciated his epochal "Law of hysteresis," one could hear once or twice a week at least, as comment on alleged advances in the dynamo electric arts, a laughing quotation of the similar Kazoos' apothegm that "Dynamos may be painted any color without increasing their efficiency."

Yes, there is still some vital savor, some drop of red blood, some human appeal in all the dim and dusty records of humble beginnings on which rests with superimposing crush the colossal electrical structure of today. As President in 1887, the writer was proud to assert that the total capitalization of all American electrical industry was about $375,000,000. This week the Institute awards its Edison Gold Medal to the member whom it has recognized as chief engineering exponent of just one of its industries—that of electric light and power—which alone has now attained an investment of Six Billion Dollars, and employs thousands of its member electrical engineers in most varied capacities.

Best of all, perhaps, above and beyond the archaic technical record of those early dingy volumes of "TRANSACTIONS" is the undying evidence they embody that even then while the older men were prophecying estactically as to a world to be wholly electrified in the near future the young men were transforming wild dreams into sober realities as arts and industries, careers and utilities. A great national society that had the courage to take for its third President an untried young man of 30, still calls youth to its banners, must forever renew its own life from the well spring of youth, and will forever with higher aims, higher ambitions, higher aspirations, higher service, interpret the engineering science that leaves no department of human affairs without benefit of its healing touch, and asseverates truthfully and reverentially; "Behold, I make all things new!"

PRESIDENT RYAN: The next speaker is an eminent American who is responsible among other things for having caused General Carty to put those twists into the telephone that serve us so well today. He did many things of wonderful value aside from that. He gave us the first electric meter that the customer could read, and with which to satisfy himself in regard to his bill.

We have had three great international electrical conventions in our country, two of which, as I remember, were referred to by Mr. Martin; the first being the one in Philadelphia under the auspices of the Franklin Institute; the next one in Chicago, in 1893, and the third and last one in St. Louis in 1904.

This gentleman carries the fine distinction for us in this country of having been elected unanimously President of each of the last two international electrical congresses.

I take very great pleasure in calling him up to speak likewise of the early days of the Institute. Mr. Martin has spoken of the wonderful things that are to be found in the archives of that day. I must speak of the gentleman who will thus quickly be called up as a prophet, for if you do not realize that he is truly one of

our great prophets, turn to the TRANSACTIONS in the fall of 1889. He was the President of the American Institute of Electrical Engineers in that year, and while in London was inspired to speak in a prophetic fashion. It is truly wonderful to read what our TRANSACTIONS say at that time.

ADDRESS OF DR. ELIHU THOMSON

In commemorating, on this occasion, the completion of the fourth decade of our Institute, it is difficult for us early pioneers to realize that much of our present membership has no knowledge, from actual contact, of the beginnings of our Institute, from which have been built up the enormous volume of electrical engineering today. Incidentally, it has given birth to the profession which our Society represents, the profession second to none in the wide world.

As its President, as has been mentioned by our own President now, in the fifth year of the existence of the Institute, it was my duty to represent the Institute at a large gathering and dinner at the Guild Hall in London, at which about three hundred of the most prominent engineers of London met, and a visiting body of Americans, mostly Civil, Mechanical and Mining, with a sprinkling only of those who had begun their activities in the electric side of engineering. I felt almost as an interloper, a trespasser on the older domain, but did my best to dignify the new profession in response to a toast to our infant society.

I want to interpose here that just before I was called upon to speak, naturally a youngster among a great many much older men, I received a message. The speaker who represented the American Society of Mechanical Engineers couldn't be heard ten feet away. I was close to him myself, and I couldn't hear what he was saying. He read too meekly altogether, and there was such a roar in the audience that nobody could expect to be heard even if he talked much louder than he did.

At that moment I received a little scrap of paper from Professor R. H. Thurston of Cornell. He said, "Thomson, it is your turn next. For God's sake, get them back. Get them back, for God's sake."

I nodded to him I would. Now, it was a big job for any one to do, but I yelled as I never yelled in my life before. I took in my lungs full, and I let it out with almost every word, and the actual fact was that I did get them back.

They quieted down, and I think most of them heard everything I had to say. I have forgotten what it was all about, but I was bound to make this little engineering institute count for something, even among that great body of men, and I was free in my predictions of what was to come in the electrical engineering field, naturally, because I believed they were to be true, and whenever I have made such predictions and found out afterwards that they actually happened, I found that several hundred per cent more has happened than I could possibly predict, so I was justified.

Lord Kelvin, then Sir William Thomson, was there. We had met once before at Philadelphia at the Electrical Congress in 1884, held in connection with the Franklin Institute Electrical Exhibition in the fall of that year. I have liked to regard him as a representative of the theoretical and practical side of electrical engineering. He it was that first understood the meaning of capacity and inductance in submarine cables, which led to the laying of the first Atlantic Cable in 1866 after the failure in 1858, due largely to imperfect knowledge of others.

His insight at that early day was most exceptional. Not since the days of Franklin's kite experiment here in Philadelphia, had there been any electrical engineering undertaking of any magnitude.

Franklin's lightning rod was a great thing and still is the foundation of our protective means for lightning.

Except for a lighthouse lamp here and there run by alternating current a single generator to a single arc-light there was not until about the middle of the decade between 1870 and 1880 any marked progress in what might properly be called electrical engineering outside of land and cable telegraphy.

There was no field for one who felt that his tendencies led him in the direction of large electrical application—he must create that field. At the centennial exhibition of 1876 here in Philadelphia, there were only two exhibits of dynamos in action; the Gramme, unique as it was, and the Wallace-Farmer; the latter long ago obsolete because too inefficient. Both of them were a development of the ideas of Paccinotti of the previous decade.

Here and there was an example of the earlier shuttle wound armature Ladd and Wilde machines, and the only one of which I knew as existing in this country was at the University of Pennsylvania in the collection of philosophical apparatus. I knew Professor Robert E. Rogers, who was professor of natural philosophy at the University. When I first saw this early type of dynamo operated in the years just after 1870, I remember standing before it spellbound. Something of the significance of thus turning mechanical power into current for the future overcame me, though the machine itself was crude and inefficient. The earlier types of permanent magnet machines of Saxtor and others made no such impression. The magneto electric had given way to the self-excited field machine of unlimited power and capabilities as seen by a sort of prevision. This principle of self-excitation came to be known as the "reaction principle" and was discovered in 1866.

The Gramme exhibit at the centennial in 1876 was made more impressive by the use of such machines as an electric motor in addition to running single arc-lights, one to a machine.

It is well known that the telephone of Bell was first shown in operation to a body of scientific men among whom was Sir William Thomson, at the centennial in Philadelphia.

A curious accident which may be known to some of you, but not to others, I may as well relate. Sir William borrowed from Bell a couple of instruments, the magnet telephone. The two instruments were electro-magnetic, the one to talk into and the other to listen from. He took them abroad with him. He tried to show these two instruments to the Royal Society in England, and he failed in getting the instruments to work. Some little accident had happened to the support of the diaphragm and prevented the operation. That little accident saved the Bell patents in England. If that instrument had worked there would have been no possibility to have gotten the Bell patents in England. A patent there depends upon the introduction publicly of the invention, and as Sir William would have been the one to introduce it publicly and not Bell, Bell couldn't have had any patent.

That was one of the accidents of fate, only it happened in that case favorably to Mr. Bell.

There was another thing that happened in those days, not so favorable to Mr. Bell. When the German Patent Office was asked to grant a patent on Bell's telephone, they said, "Oh, no, it is too valuable an invention to be patented," and they refused it. In other words, the more valuable a thing a man gets up, from the German standpoint, the more definitely must he be refused a protection.

From 1874 on, while living in Philadelphia, I was constructing small machines and using them as motors and at the close of 1876 had finished a machine which required about a horse power to drive it, and which would work a small arc-light. I had wound the field shunt and series as a compound winding and used it as such, subsequently finding that a British patent to S. A. Varley had already shown such a winding in 1876. However, I made use of this machine of mine, in a course of five lectures in electricity given at the Franklin Institute early in 1877, the object of which lectures I had designed to be the demonstration of the fact that electricity from any source was indeed the same.

In 1877 the Franklin Institute appointed a committee to investigate the properties of arc-lights and machines for running them, one machine to one light, of course. Professor Houston and I served on the Committee for the electrical measurements, the first, I think, published. This was in 1878.

Then followed a more rapid advance. The Avenue de Opera was lighted during 1878, exposition year, by Jablochkoff candles, later found too expensive. Brush brought out out early in 1879 his series system of arc-lights, closely followed by Thomson-Houston in the same year.

I may say as a matter of personal note that about four blocks west of where we are now, the first T.-H. dynamo was built early in 1879.

Its armature had on it the first three-phase windings, used with the three segment commutator, of course. The patent application showed the winding of today connected to collector rings for a-c. current.

The machine was the very first of its type though of about five hundred volts and ten amperes or about five kw. No model had been made, but so confident was I of the merit of the construction for constant-current work, that I was willing to risk success. It worked perfectly from the start and lighted a bakery, near where it was built, through the summer of 1879, the room temperature on account of the large bake ovens reaching on a hot night 140 deg. fahr. Why didn't it kill us? It did nearly kill two of us, but I was the one not affected.

I am going to give a piece of advice. Houston had to lay off from heat prostration. Thomas H. McCullum, interested in the matter, had to go off from heat prostration, but I didn't, and the reason was before I got hot enough to feel very uncomfortable I drank quantities of ice water. They said, "You will kill yourself."

"No, I won't. I am keeping my temperature down," and it worked.

In 1880 our newborn enterprise was taken to New Britain, Connecticut, and later to Lynn, forming the nucleus of the great works there.

Another little personal note I may interject here. When I got to New Britain, it was a manufacturing town in the interior of the State of Connecticut. Hardware, tacks, nails, hinges, and everything of that kind were made there. They did not know anything about electrical apparatus, and didn't appreciate what we were trying to do. We got to Lynn as soon as we could, but nevertheless there was a Western plater in one of the shops. Probably some of you know the old type of multiple revolving generator.

I was the electrician (not the electrical engineer) of the town at that time, and they asked me to come and see that machine. I said, "Send it over." They put it on a wagon and sent it over. We found it was a machine of fairly large size used for working the plating bath in these hardware operations. I turned it over and took a monkey-wrench and tightened a screw on the bottom. One of the nuts that tightened up the connection was loose, and of course, with such a low voltage as plating voltage, the current couldn't cross that kind of a joint.

Late in 1879 Edison had settled on carbon as the material for a burner or incandescent lamp filament and the famous Menlo Park exhibition of such lamps running in parallel from a dynamo took place at the close of the year.

Years elapsed before the prodigious work of producing the much-needed appliances in such a new art as incandescent lighting was accomplished. The Pearl Street

Station in New York, with its direct connected jumbo dynamos and underground distributing mains, was the outcome in 1882.

The following year the Brockton Edison station was opened as the first example of city distribution by three-wire circuits. The pace of development was from now on rapid, but we have now about reached the time of the organization in 1884 of our Institute, and later that of the first electrical exhibition in the fall of 1884, in Philadelphia, the Franklin Institute exhibition where were shown in one building all the notable advances made in the years preceding.

I will not attempt to catalogue them, only to say that this event was, as it were, a most fruitful and interesting landmark in the electrical progress in our country.

Edison in 1875 had thought he had a new force, etheric force. Mr. Houston and I thought it was electrical and set about proving it. The whole account of it was published in the Franklin Institute *Journal* at the time. At the conclusion of the experiments,I said, "Let's do this thing on a big scale." So we set a tin vessel on a table, attached one terminal to the coil, and the other was connected under the table, this being insulated and had the sparks connected. When we did that we could go all over the building and outside and explore by a pencil point, which by the way, Edison had used as a detector. We went to the observatory, five floors away, and we could get from doorknobs a signal that the machine was in operation on the first floor.

This was at the old Boys Central High School, North Broad Street, about a mile away from here. The building is still there.

Was there before this anything suggestive of wireless? Yes, there was. In the old Boys Central High School, a small set of experiments was made in 1875 and 1876, pointing that way. They have been detailed elswhere.

Was there anything of transformer work known in those days? Yes. In the Franklin Institute lecture room in February, 1879, were run two transformers (induction coils) with their fine coils of many turns in parallel from the collecting ring end of a dynamo which had been constructed to be self-exciting and yield a-c. currents.

There were no incandescent lamps for the coarse short wire secondaries, so we had to be content with semi-incandescent lamps with carbon and coils of iron wire heated red hot. This is probably the first time such a combination was used, little else pointing the way.

In New Britain one of our first jobs (I am trying to give you a picture of the electrical engineering of the time) was to find out what, if any, was the loss in an armature core of a dynamo. Some had said there isn't any loss in the iron, and others had said there is a lot of loss in the iron. Some had said that if you use insulated wire you wouldn't get any loss, or very little, if you use bright wires you will, for winding the cores.

We didn't have sheet metal. I will tell you later about that.

So we set up a dynamometer, built the armature cores and ran into the excited fields to determine how much loss there really was in the iron, and we found the iron varied and the loss was in some cases much greater than others, and we selected our iron wire accordingly but we always found there was a loss outside of winding and oil, but it was very difficult to determine how much it was. It was not so serious a loss as compared with the resistance loss in the copper. So we had to go along in that way.

I want to say that sometimes we had to go to the Patent Office in those days to tell the Patent Office what we were about. They didn't understand. I tried to tell them something about the reactance induction coil, how it worked like resistance. They said, "You can't tell us that."

So I had to go down and make an elaborate description. Think what the trip to Washington cost us in those days! You left Philadelphia and went to Baltimore. Through the streets of Baltimore was a line of mule teams, and they took the coaches and pulled them. That was in 1880. Those whose memories can carry them back to that time will bear me out. It wasn't an easy job to get to Washington in those days.

Everything in those days depended on regulation by hand, and it was only later that we got into automatic regulation.

Now, I want to say just a word before I stop as to the handicaps we were working under in those days, the days just before the organization of this Institute.

Wire: How and where could we get wire? In Philadelphia there was a bonnet wire factory. As you know bonnets in those early days were made of wire, braided or wound with cotton. That bonnet wire factory did on the side a little business of winding cotton on copper. That is the way we had to get the wire for dynamos we were constructing. We had difficulty as late as '84 or '85 in getting the fine wire in the shunt circuit in arc-lights, which should have the same resistance. We should have coils of the same resistance; we gaged the wire at one end of a hank, and it was smaller than at the other end, or larger than at the other end. During the time of pulling the thousands of feet of wire through that die, the die wore, and the wire got bigger and bigger all the time. That was one of the difficulties that we had.

How could we make coils that would measure up to any definite resistance? Well, I had to take the wire makers into my confidence and say, "We won't buy that wire unless you jewel draw it. You have to draw it through jewel dies. That is the way it will have to be done."

They set up the jewel dies. They advertised that they had now the process of producing wire the same at one end as at the other, and they never gave me any credit for it.

It was the same with the insulations. The insulations were poor, and our line wire was poor; even bare wire was used in those days to distribute arc-lighting. All of us who go back far enough know that the loops that went into stores and the wires on the poles were bare copper, and had forty arc-lights or more.

I know one place where they tried to couple up in 1882 seven of the Brush type in Cincinnati on bare wire alone. It is a wonder they didn't set the whole place on fire, but the fact of the matter was, they broke down all the machines so they couldn't set it on fire.

We had no slate and porcelain. Mica was used for stove doors, and that is all there was, and it was ourselves that introduced mica and pasted it together for the insulation in our arc-light machines.

Permanent Magnets: We had to study and manufacture magnets for our meters and study the whole case of production of permanent magnets and how to season them so they would be permanent. Otherwise the meter was no good. Those were the things we had to do. Nothing had been done for us. Remember the steel we had was only tool steel. We hadn't any special magnet steel such as we have now.

In 1878 there were no telephones. You couldn't call up anybody by 'phone.

There were no typewriters. We had to do all our writing by longhand, and have it put in a copy book. The typewriter came later. There was an awful lot of work done in those days that people don't have to do nowadays.

There were no steam engines in those days, and that applies directly to the time of the start of the Institute. The engines of those days, except for some special instances where they were made for it, were not good enough to drive electric machinery. You know the old slide valve engine found everywhere. They thought they would put electric lights on those old engines, and every time they moved the lights went up and down.

It was the development of the high speed engine that made it possible to drive the jumbo dynamo at such a speed. It couldn't give an output without belting. Everything was belted before that direct connection. All the machines were belted to the engine power and subject to the vagaries of old-fashioned governors.

I could go on and tell you more and more about the difficulties, but things came gradually, sheet metal, sheet iron. We have been even criticized at times by being asked, "Why didn't you use sheet iron in those early machines?"

We couldn't get any sheet iron except stove pipe iron. That wasn't any good for magnetic effects. We would have been glad to get punch presses and use sheet iron, we couldn't get it. More than that, the punch presses in those days were used to punch out pie plates. There was not much done. The punch press now is the wonderful institution of any great electrical works. We had to design our machines to fit the tools we had in the shop. If we did not have a big enough planer to take a machine, we had to design a machine so the planer would take it. That will explain some of the designs that we had to use. We didn't have any steel castings in those days. There weren't any steel foundries that were producing steel castings. It was only in 1886 that we established a steel casting foundry in Lynn.

I will weary you if I keep on, but I wanted to give you a sort of an idea of the fact that things were not in those days as they are today.

President Ryan: The first year as instructor in college, I was called upon to proctor in an examination in Greek life. It was a new experience. I looked over the list of questions and found that there was but one in regard to which I could conjecture anything. However, I had no responsibilities in the matter in that regard. It didn't matter whether I could conjecture anything or not in regard to the examination. I had not the questions to write or the papers to read. The question that appealed to me was this one: "In the understanding of the wise men of ancient Greece, what was the limit in population of a city?"

When the papers began to come in, I looked them over. Four or five sufficed. It was an easy question to answer, evidently. The answers were all in agreement, and I came to the conclusion I knew the answer. The answer was this interesting one: "No city in the understanding of the wise men of ancient Greece in population could grow beyond a point whereat the people might gather around the city's advocate and hear his voice and learn the truth."

I wonder what a wise man of ancient Greece would think today to come into our country and find that through the wonderful work of the next speaker and the organization that he built up, there is no limit to the size of a city in population. For in 1915 he extended his lines clear across the continent and from that day to this, at any time if we care to, it is physically possible for us as a nation to sit down at home, or nearly so, and listen to the voice of the President of our great country.

I take great pleasure in calling up as the last speaker in this series, a past President of the American Institute of Electrical Engineers, General Carty.

Address of General Carty

Among the four national engineering societies, composed of Civil, Mining, Mechanical and Electrical Engineers, the Society of the Electricals is the youngest. Of the other societies mentioned, it may be said that the art which they represent existed before they were formed, but of the Electricals it can be said, with pardonable pride, that its members created their own art.

The Centennial Exposition, held here at Philadelphia in 1876, marked the beginning of a new era in electrical

development. Prior to that time the use of dynamos had practically been limited to such purposes as electroplating, and electric motors were a curiosity—a toy, not for children, but only for college professors to play with. The principal use of electricity was in the different forms of signaling, of which the telegraph was the most important.

At the Centennial Exposition in Philadelphia, one who was to become a member of the American Institute, and also one of its Presidents, Dr. Alexander Graham Bell, made known to the world his invention of the telephone. This gave a wonderful stimulus to the advancement of electrical science.

Soon followed the invention of the phonograph and the astonishing development of the dynamo and the electric light, which we so largely owe to another who was to become one of the members of our Institute yet to be formed—Mr. Thomas A. Edison.

Working here at Philadelphia about this time, there was another whose name was destined to be memorable in the annals of our Institute—Dr. Elihu Thomson. His fundamental work in laying firmly the foundations of the art of electrical engineering will serve as an inspiration to our members during the years to come.

Between the years 1876 and 1884, such marked progress had been made by the electrical pioneers, the future founders of our Society, that the importance of forming a national electrical engineering society was recognized, so that in 1884 the electrical pioneers of the period joined in the formation of an organization which should be a worthy exponent of electrical progress throughout America.

Prior to the work which was done by these pioneers, many of whom are still alive and active members of our society, there was no art of electrical engineering, and there was no university conferring the degree of Electrical Engineer. Electrical engineering was not even recognized among the professions. Those who devoted themselves to the practical affairs of electricity were known as electricians—a term now generally applied only to electrical artisans.

It was our society and the work of our members which have secured for electrical engineering its present position among the foremost of the learned professions.

Since the formation of the American Institute of Electrical Engineers, progress in electrical engineering has been a record of rapid and continuous and marvelous achievement.

The story of this achievement is to be found in the history of the American Institute of Electrical Engineers and in the careers of its members. So numerous and so important are the contributions of our members that adequately to describe them would require the writing of the history of the art of electrical engineering.

While our colleagues of the Civil Engineers were celebrating the joining of the Atlantic Ocean and the Pacific Ocean by the Panama Canal, the members of the American Institute of Electrical Engineers were celebrating the joining of the Atlantic Ocean and the Pacific Ocean by electric wires spanning the continent and carrying the human voice from coast to coast.

It is among our membership that we find the men, who, taking the feeble telephone which Bell exhibited at the Centennial Exposition in 1876, have built upon it the entire art of telephony, and have constructed telephone lines and installed telephone stations so that it is now possible to transmit the human voice from San Francisco to all of the states in the Union, connecting with wire systems reaching more than fifteen million stations and aggregating more than forty million miles of wire, representing an investment of more than two billion dollars, and carrying more than nineteen billion messages in a year.

In our membership are to be found men who have developed the wonderful art of electric power transmission, whereby the melting snows of our mountains are transmuted into power and light and heat and current for transmitting speech, for lighting the homes of our nation, for propelling railroad trains and ministering in countless ways to the happiness and welfare of our people.

It is a great satisfaction to our members to observe these important contributions which they have made to the comfort and beauty of the homes and the halls of our country.

In the progress of society from the primitive conditions found in former times to the present high state of civilization, communication and transportation have been the two great forces in the building up of the civilized state. It was said before the founding of our government that west of the Alleghanies there never could be a people which could form a part of a nation on the Atlantic Coast. This was because of the impossibility of communications and transportation, which are essential to a community of interest and common action.

This indeed was true at the time, and would still be true were it not for the work of engineers. Communication north and south along the Atlantic Coast was accomplished well enough at the time by coasting vessels plying between the numerous harbors which there abound, but it was not until the advent of railroads, which were the work of engineers, both civil and mechanical, that the growth of our country westward as a permanent part of our nation, was assured, and it was not until the great State of California was connected by rail with the East, that our Union was complete.

Coextensive with the development of the railroads came the telegraph, supplying communities with the great essential, quick communication. Thus, with the railroad, the telegraph and the mail, the essentials of growth for the time being were provided, but as our progress has become more complex, further develop-

ment of transportation and communication was required.

Our members have provided these in the telephone and in the electric railroad. The telegraph and the steam railroad connect places; the telephone and trolley reach directly to homes and to offices. They connect not only places, but they connect people. In many other ways that are little thought of, our membership has contributed to the upbuilding of our nation.

The American Institute of Electrical Engineers stands for the highest achievement in electrical engineering and for the most distinguished attainments among its members.

From the art of electrical engineering as its exists in the world today, take away the contributions of the members of the American Institute of Electrical Engineers, and that which would be left would make a sorry showing by comparison.

The art of telephony would disappear and all of those wonderfully coordinated activities of both peace and war, depending upon that means of communication, would instantly be paralyzed.

In electric lighting and power and current distribution, the contributions of our members have been so fundamental, so important and so numerous that it is impossible to picture the chaos which would result if, by some black magic, their wonderful work should be undone.

By its papers and meetings and discussions, by the spread of knowledge through its published JOURNAL and TRANSACTIONS, and above all, by the high ideals of its members and by the unsurpassed character of their achievements, the Institute has taken a foremost place among the forces making for the welfare and unity of mankind.

It is with feelings of pride and satisfaction that today we celebrate the fortieth anniversary of the founding of the American Institute of Electrical Engineers.

We are holding this celebration in the Golden Age of Electricity—the age of electrical communications, of electrical transportation, the age of light and power. What words these are to conjure by! Light to see, and power to *move* and to do—to do that which no man has done before. What inspiration they send forth, urging our members to still greater achievement!

ALL-ELECTRIC DREDGES LAUNCHED

Two all-electric, 2000-ton capacity hopper dredges built for the Engineer Corps were recently launched from the yards of the Sun Shipbuilding Company. These dredges are electrically driven throughout, no steam being generated on the ship. The main propulsion is obtained from Diesel engines driving direct-current generators which, in turn, operate the propelling motors. Electricity is used for cooking, heating, ventilating, and all other purposes. These are probably the largest vessels that have been completely electrified and mark a new step in the progress of the art.

ILLUMINATION ITEMS

By the Lighting and Illumination Committee

THE EFFECT OF MODERN ILLUMINANTS ON THE EYE[1]

DR. GEORGE S. CRAMPTON

We are told on the best of authority that factory and other work efficiencies are enhanced by increase of illumination. Are we then speeding up our bodies at the expense of our eyes? While there are but little experimental data upon which to base such an opinion at the present time, much good work bearing upon another phase of the question makes it possible to state without much fear of contradiction that if the lighting, although of high intensity, be properly arranged in relation to the work, not only will no harm result but there will be an actual benefit.

In the first place, in order to make a true estimate as to whether or not we are harming our eyes, we must be sure that we are dealing with eyes that are operating under full or normal efficiency. Visual fatigue tests, for instance, conducted on a subject having other than emmetropic or normal eyes mean but little, even though he be wearing a correcting glass, as under these conditions variable factors may alter the results.

One frequently hears a lighting installation condemned by a person who would find it most excellent were he wearing the proper glasses. Any one who is compelled to work steadily on fine details under any sort of illumination should be sure that an uncorrected or partially corrected astigmatism is not gradually sapping his nervous energy. And if he be of the age when the accomodative or focusing power is defficient, say from forty to forty-five years and older, he should be sure that his glasses fully relieve him of his strain. At this age full and ample illumination is essential.

There is probably no more highly organized muscle than the ciliary body which controls the focusing of the crystalline lens and none that will cause more distressing symptoms when forced to function under adverse conditions.

As our years advance the natural elasticity of the lens gradually decreases to the point where artificial aid must be given to permit near seeing, especially in reduced light. Almost all normal-sighted and so called far-sighted people who have reached this period of life will recall their first symptoms of decreased focusing power which became evident when trying to read a time-table or telephone book in a poor light. Ample illumination suffices for a while to stimulate the lagging focusing power and then resort must be made to a glass of increased strength for near work, generally in the form of bifocals. From then on, full illumination is necessary to comfort. We can hardly realize the discomforts experienced by our early ancestors who had neither proper glasses nor adequate light in the evening.

The complaint is often made that a person is forced to work all day by artificial light. With our present facilities this is not a legitimate complaint, that is, if

1. I. E. S. *Transactions*, January, 1924.

the individual is not forced to accept the general illumination of the work room. I feel sure that ample artificial light, properly placed and shaded will not cause more, and often not as much, fatigue as daylight which is subject to all vagaries of cloud, bright areas, and improper direction.

The element in artificial light which seems to have caused the greatest anxiety and alarm has been the ultra-violet radiation and until recently its deleterious effects have been very much over-rated. In the beginning the fact seems to have been overlooked that the much vaunted natural light contains infinitely more of the ultra-violet than the strongest of the artificial sources. The radiation from the more powerful lamps, especially those of the mercury vapor and other arcs, does contain a certain amount of ultra-violet but under the usual condition of installation this will cause no harm to the eyes. Even though it were many times more powerful, there would be no permanent deleterious effects, as was shown by Verhoeff and Louis Bell in their experiments on rabbits, monkeys, and the human subject in which they proved that the retina may be flooded with light of extreme intensity (not less than 50,000 lux) without any sign of permanent injury. This is due, of course, to the fact that the corona and crystalline lens of the eye, together with the fluid media act as a filter to the ultra-violet and prevent it from reaching the retina in strength sufficient to do harm.

To injure the corona, iris, and lens by the thermic effects of radiation requires a concentration of energy obtainable only under extreme experimental conditions.

Infra-red rays have no specific action on the tissues analogous to that of abiotic or ultra-violet rays. Actual experiments made on the human eye show conclusively that no concentration of radiation on the retina from any artificial illuminant is sufficient to produce injury thereto under any practical conditions.

A year or so ago we examined the retinas and crystalline lenses of fifteen men who had been employed for a considerable period in electric welding on street railway tracks, and all were found to be free from any injury, although most of them at one time or another had had ultra-violet burns of the face and eyes, of a surface nature, due to accidentally striking the arc before their faces were shielded by the mask. This type of burn is merely a sunburn and although exposure to an iron arc for a few moments may cause distressing symptoms, which come on several hours later with the feeling of sand in the eyes, the trouble soon passes and no harm results.

Thus it may be seen that we may speed up industry and surround ourselves with the cheeriness of ample illumination without causing any harm to the eyes. But one note of warning must be sounded and that is to beware of placing lamps of high intrinsic brilliancy in old shades that are too short for them, thus exposing the eyes to the glare of a bare filament.

Glare must be avoided if we are to have eye comfort as the iris becomes fatigued by being alternately cramped to small pupil and relaxed as darker areas come into view.

GOOD LIGHTING VITAL TO INDUSTRIAL SAFETY

"Almost every measure put forth to safeguard industrial employes against accidental injury requires, as a primary and fundamental condition, proper lighting," states A. C. Carruthers in *Safety Engineering* the official publication of the American Society of Safety Engineers.

"It presupposes that at all times the operators will be able to see clearly and distinctly in performing their duties and moving about the plant, but in a great many cases the proper lighting has not been furnished and the beneficial results which could and should be secured through the safety devices and other protective equipment and apparatus, safety rules and safety instructions imparted to the employes, have not yielded the expected results. Proper lighting is a very important safety measure and it removes a very definite and now well-recognized hazard of industry.

"It is safe to say that a large number of accidents both fatal and non-fatal have occurred because of bad lighting conditions, but industry has paid the price, both employer and employes having suffered severely through this insidious hazard. Few, if any, industrial hazards can be removed so completely from the midst of a busy industrial plant as the bad lighting hazard.

"Seven states have thus far adopted State Lighting Laws, based upon standards which aim to protect workers in industrial plants from accidents due to bad lighting and from unnecessray eye-strain. The states that have passed laws making obligatory definite industrial lighting standards are New York, New Jersey, Pennsylvania, Wisconsin, Oregon, Ohio, and California."—*Transactions* I. E. S., December 1923.

NOTE—Massachusetts has adopted a similar code, which became effective Jan. 1, 1924.

CONTINUED INCREASE IN STREET LIGHTING

The North Side of Pittsburgh, known as "Old Alleghany," will be "New Alleghany" as far as street lights are concerned. 2113 lamps of 600 candle power each are displacing the ancient arc-lighting system. Under a new contract, the city will pay $1.00 more per light per year than formerly, a good investment in vastly superior illumination. Philadelphia is doing the same thing on Broad Street, using 1000 candle power lamps. St. Louis has started work on its $8,000,000 city-wide street lighting program. Danielson, Connecticut; Utica, N. Y.; Sioux City, Ia.; Longview, Washington; in these and in dozens of other towns, street lighting is being modernized.

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The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.

Birmingham Ready for the A. I. E. E. Spring Convention

Southern engineers will welcome the Institute in Birmingham on April 7-11 for the first time in many years and preliminary reports indicate that each visitor will have a generous share of the famed Southern hospitality. The local convention committee through its chairman, W. E. Mitchell, reports a cooperative movement throughout the whole South among Institute members for making the meeting a memorable occasion. A glance at the tentative papers shows that a very interesting and well balanced program has been prepared, which has a national aspect through having papers by authors from all parts of the country who stand in the front rank of engineers.

With the great interconnected systems already in operation in the South and the marked hydroelectric developments already completed, it is fitting that water power, transmission and allied subjects should appear prominently on the program, but in addition, notable papers will be given on mining applications, metallurgical applications and machine developments with a resulting balance and quality which should attract many visitors. Of particular interest in the technical sessions is the presentation of developments and practises in different parts of the country, for this will stimulate splendid discussions and produce a clearing house effect on controversial technical practises. Hydraulic equipment, oil breakers, lightning arresters and electric furnaces are some of the subjects thus treated which should create very good discussions.

Special Features on Tuesday

The Convention Committee in cooperation with the Meetings and Papers Committee is particularly fortunate in the special program for Tuesday afternoon and evening. This program deals with water-power and interconnection on a national scale by taking Southern developments as typical of what can be done in securing interconnection of many systems for the supply of electrical energy. Notable speakers will treat the subjects from all angles and record in their addresses material that will be new and pertinent to national power development on a large scale. These speakers and this program alone should be sufficient inducement for many members to attend the convention from distant sections.

Birmingham and Vicinity Unusually Interesting

But aside from the scheduled sessions and the papers presented, there are many inducements for engineers to attend a convention in Birmingham. The city has a unique location in that an extensive coal deposit on one side is balanced by an almost inexhaustible iron-ore deposit on the other, while the near vicinity has large waterpower developments and resources. This has resulted in the formation of a very large industrial area in the vicinity of Birmingham and the development of the necessary

MITCHELL DAM, ALABAMA POWER CO.

power resources to maintain this activity. Iron mines, coal mines, steel mills, textile mills and allied industrial activities are highly developed and will be made available to convention visitors. Familiar names, such as Lock 12, Mitchell Dam, Gorgas Steam Station and Muscle Shoals are connected with nationally known power developments, which may be visited readily in connection with the convention. Also an opportunity is offered for seeing one of the greatest interconnected systems in the country. Transmission lines are connected from Tennessee, through Alabama, Georgia, South Carolina into North Carolina and the group of companies thus interconnected have actual operating experiences which have a great bearing on the possibilities of interconnection for other parts of the United States. Many of their engineering practises and much of the equipment have been developed along unusual lines, because of the interconnections existing and should be interesting to engineers from other sections.

Social Features Accented

A Southern convention will naturally have social and entertainment features of an unusually delightful character and reported plans from the local committee seem to indicate that every visitor will participate in non-technical activities of un-

Lock No. 12, Alabama Power Co.

usual attraction. Golfers will be welcomed to the Birmingham Country Club and to the Roebuck Country Club, each of which has splendid courses. Teas and entertainments are prepared for the ladies together with automobile trips of interest. On Monday evening the convention will attend an informal reception and dance at the Birmingham Country Club but the climax is being planned for Wednesday evening, when, if all goes well, a genuine old-fashioned Southern barbecue will be held on the top of Shades Mountain, seven miles from Birmingham. Those who have never participated in a savory entertainment of this character can anticipate an eventful and delightful experience.

Inspection trips to industries in the Birmingham district are scheduled and on Friday it is planned to take the whole convention to see Lock 12 and Mitchell Dam—two notable hydroelectric developments.

Register As Soon As Possible

Headquarters will be at the Tutwiler Hotel. In order that arrangements may be completed, every member who plans to attend is urged to communicate as early as possible with Mr. W. J. Baldwin, Chairman of the Hotel Committee, Alabama Power Company, Birmingham. He should be notified as to date of arrival and accommodations desired. Definite reservations, however, should be made by individual members through the hotel management. The committee which has charge of the convention is composed of the following members: W. E. Mitchell, Chairman, W. J. Baldwin, J. M. Barry, H. E. Bussey, Howard Duryea, H. W. Eales, B. C. Edgar, J. E. Fries, H. M. Gassman, L. W. W. Morrow, A. M. Schoen and F. V. Underwood.

TENTATIVE PROGRAM FOR BIRMINGHAM CONVENTION

Monday, April 7

9:30 A. M.

Committee Meetings and Registration.

2:00 P. M.—Technical Session

Hydroelectric Practises and Equipment in the South, by O. G. Thurlow, Alabama Power Company.

Hydroelectric Practises and Equipment on the Pacific Coast, by S. Barfoed, Consulting Engineer.

Developments in Hydroelectric Equipment, by W. M. White, Allis-Chalmers Company.

Acceptance Tests on Hydroelectric Stations, by F. H. Rogers, Wm. H. Cramp and Sons.

8:00 P. M.

Informal Reception and Dance at Birmingham Country Club.

Tuesday, April 8

9:30 A. M.—Two Technical Sessions in Parallel

Session (A)

Lightning Arrester Experience on the Coast, by E. R. Stauffacher, Southern California Edison Co.

Lightning Arrester Design and Operation, by C. E. Bennett, Georgia Railway and Power Company.

Economics of Lightning Arresters, by A. L. Atherton, Westinghouse Electric and Mfg. Co.

Operating Experience with the Relaying on the Duquesne System, by H. P. Sleeper, Duquesne Light Company.

Session (B)

Electrical Safety in Coal Mines, by L. C. Ilsley, U. S. Bureau of Mines.

Automatic Substations for Mines, by C. E. Von Sothen, General Electric Company.

Tests on Mine Hoist Control, by F. L. Stone, General Electric Company.

2:00 P. M. and 8:00 P. M.—Sessions on Southern Water-power Development

Analysis of Water Powers of the South, by C. O. Lenz, Consulting Engineer.

National Water Power Development, by O. C. Merrill, Executive Secretary, Federal Power Commission.

Southern Power Developments, by Thos. W. Martin, Pres., Alabama Power Company.

Public Relations in Power Development, by Preston Arkwright, Pres., Georgia Railway and Power Company.

Financial Aspects of Hydroelectric Developments, by H. M. Addinsell, Harris, Forbes and Company.

Gorgas Steam Plant, Alabama Power Co.

New Type of High Tension Interconnecting Network, by Percy H. Thomas, Consulting Engineer.

Wednesday, April 9

9:30 A. M.—Technical Session

High-Tension Oil Circuit Breaker Tests, by H. J. Sholtz, Alabama Power Company.

Alabama Power Company Breaker Tests, by R. W. McNeill, Westinghouse Elec. and Mfg. Co.

Oil Breaker Tests, by A. J. D. Hilliard, General Electric Company.

Oil Breakers from an Operators Viewpoint, by J. V. Jenks, West Penn Power Company.

P. M.

Inspection Trips to Developments in the Birmingham District.

6:30 P. M.

Old-fashioned Southern Barbecue on Shades Mountain.

Thursday, April 10

9:30 A. M.—Technical Session

New Synchronous Induction Motor, by Val A. Fynn, Consulting Engineer.

65,000 Kv-a. Generators at Niagara Falls, by W. J. Foster and A. E. Glass, General Electric Company.

Harmonics Due to Slot Openings, by C. A. M. Weber, Westinghouse Electric and Mfg. Co., and F. W. Lee of Johns Hopkins University.

22,000 Kv-a. Transformers at Niagara Falls, by F. F. Brand, General Electric Company.

2:00 P. M.—Technical Session

New 20-16 in. Strip Mill, by Noble Jones, West Leechburgh Steel Company.

Maximum Demand Regulator for Electric Furnaces, by E. T. Moore, Halcombe Steel Company.

Manufacture of Phosphoric Acid in Electric Furnaces, by Theodore Swann and F. V. Andrea, Federal Phosphorus Company.

Symbolic Curves, by J. T. Fries, Tennessee Coal, Iron and Railroad Company.

Effect of Impurities on Battery Electrolyte, by G. W. Vinal and F. W. Altrup, U. S. Bureau of Standards.

Friday, April 11

Inspection Trip and Visit to Lock 12 and Mitchell Dam.

Enjoyable Program for June Convention

A pleasant and most profitable visit is anticipated by all who plan to attend the Annual Convention at Edgewater Beach (Chicago) in the week of June 23. As is suitable for the Annual Convention, a large part of the time will be devoted to the lighter side of convention activities which include social, entertainment and sports events. Edgewater Beach, located several miles outside of Chicago, on Lake Michigan, is a most pleasant place to visit as there are many facilities for sports and social features.

The technical papers promise to be very interesting. They will deal largely with transmission and distribution in metropolitan districts and with standardization. In addition, the various technical committees will present reports on the year's developments and their plans for future study.

So far as is possible at this time, the program has been arranged to include the following technical sessions:

Technical Sessions Planned for June Convention

1. Automatic Substations—five papers.
2. High-Voltage Cables—four papers.
3. Metropolitan Distribution—four papers.
4. Standardization—three papers.
5. Transmission and Protection—four papers.
6. Reactors—four papers.
7. Reports of Technical Committees.
8. Miscellaneous—three papers.

A. I. E. E. Directors Meeting

The regular bi-monthly meeting of the Board of Directors of the American Institute of Electrical Engineers was held at the Bellevue-Stratford Hotel, Philadelphia, on Thursday, February 7, 1924.

There were present: President Harris J. Ryan, Stanford University, Calif.; Past President Frank B. Jewett, New York; Vice-Presidents W. I. Slichter, New York, H. E. Bussey, Atlanta, William F. James, Philadelphia; Managers Harold B. Smith, Worcester, Mass., E. B. Craft, H. P. Charlesworth, New York, R. B. Williamson, Milwaukee, A. G. Pierce, W. M. McConahey, Pittsburgh, Harlan A. Pratt, Hoboken, N. J., G. L. Knight, Brooklyn, N. Y., W. K. Venderpoel, Newark, N. J.; Secretary F. L. Hutchinson, New York.

The federal income tax legislation was discussed and the following resolution adopted:

Resolved: That in view of the great importance to the engineering profession of the pending federal income tax legislation, the members of this Institute be urged by this Board to write promptly to their Congressmen and Senators, conveying their individual views regarding this important subject.

Upon the recommendation of the Board of Examiners the following action was taken upon pending applications: 77 Students were ordered enrolled; 551 applicants were elected to the grade of Associate; 9 applicants were elected to the grade of Member; 4 applicants were transferred to the grade of Member; 4 applicants were transferred to the grade of Fellow.

Upon recommendation of th Committee on Student Branches, a request for authority to establish a Student Branch of the Institute at the University of Florida, Gainesville, Florida, was granted.

Announcement was made of the appointment by the President of the Tellers Committee to canvass and report upon the nomination and election ballots received in connection with the 1924 election of Institute officers, as follows: J. B. Bassett (Chairman), A. E. Bauhan, Irving W. Green, R. R. Kime, and Benedict Tikhonovitch.

A communication was presented from the secretary of the U. S. National Committee of the International Electrotechnical Commission to the effect that in accordance with the statute of the committee the terms of all members had expired, and that the A. I. E. E. should now make new appointments. The Board voted to authorize the President of the Institute to make the necessary appointments upon the U. S. National Committee of the I. E. C.

In accordance with previous action taken by the Directors authorizing the appointment of Local Honorary Secretaries in several foreign countries in which there are at least twenty members of the Institute, the following Local Honorary Secretaries were appointed: T. J. Fleming, for Argentina; Eiji Aoyagi, for Japan.

The Secretary called attention to the desirability of improving the election procedure of the Institute, and recommended that a committee of the Board be appointed to study this subject. The Board voted that the President be authorized to appoint a committee of three members of this Board to study the entire election procedure of the Institute and to make such recommendations as the committee may deem desirable.

The Secretary reported that the plans for the World Power Conference to be held in London June 30—July 12, 1924, are rapidly maturing; that the American Committee has held a number of meetings and has arranged for the presentation of a number of papers by Americans, most of whom are members of one or more of the national engineering societies, including several members of the A. I. E. E.; that the American Committee has appointed Thos. Cook & Son as official transportation agents. and that the steamship "Scythia" of the Cunard Line, sailing from New York June 19 and arriving in London June 28, has been selected by the committee as the most suitable for the accommodation of Americans who will attend. Attention was also called to the fact that the British societies of Civil, Mechanical, and Electrical Engineers are all arranging several meetings and other functions to be held during the week following the World Power Conference.

A report was submitted from Mr. C. E. Skinner, a representative of the Institute on the Board of Management of the World Congress of Engineers to be held in Philadelphia, in 1926, to the effect that a committee to consider plan and scope has made a preliminary report, and that it has been tentatively decided that only general topics will be discussed and not detailed technical papers which would ordinarily be presented before the societies representing the various branches of engineering.

Reference to other matters discussed may be found in this and future issues of the Journal under suitable headings.

International Commission on Illumination

A limited number of copies of the Report of the 1921 Paris Meeting of the International Commission on Illumination are available to interested parties by enclosing ten cents for postage to Howard Lyon, Secretary-Treasurer, U. S. National Committee of the International Commission on Illumination, Welsbach Company, Gloucester, New Jersey.

The Philadelphia Midwinter Convention

The Largest Convention in the History of the Institute, with the 40th Anniversary, Edison Medal Presentation, Moore School Dedication and Transportation Meeting as Special Features.

The 12th Midwinter Convention last month was the first of its kind to be held outside of New York City, and doubt was expressed in some quarters as to the feasibility of changing the location of this function which had always been a pronounced success in New York. The convention in Philadelphia, however, dispelled all doubts on this score as it proved to be the largest convention in the history of the Institute, with an attendance of 1738 registered members and guests.

The midwinter conventions are generally regarded as the working conventions of the year, in the sense that the results of research, new inventions and improved practises of the previous year are discussed at this time. The Philadelphia convention excelled all traditions by presenting a well-balanced program of 40 high-class technical papers which received a full share of thorough discussion.

Aside, however, from the record attendance and excellent technical program, there was much additional interest in the special features which gave a large measure of human interest and comradeship that is so frequently missing in meetings of a strictly technical character. These features included the 40th anniversary celebration at which reminiscences of the early history of the Institute were recounted by several of its charter members; the Edison Medal presentation, which always carries a strong personal appeal; the dedication of the Moore School at which four of the past-presidents of the Institute received honorary degrees, and the transportation meetings with addresses by several prominent leaders in the railroad and industrial fields.

The number and variety of inspection trips and other entertainment features were in keeping with the excellence of the entire program. Philadelphia is especially favored with numerous historic points of interest which were widely visited by the delegates and guests in attendance, and all of the electrical public service and manufacturing companies in the city and vicinity courteously threw open their plants and provided guides for the benefit of visitors. Entertainment for the ladies was also lavishly provided. A special folder entitled "While the Men Work" was distributed, which outlined day by day the recreation and entertainment features available to the ladies during the convention.

From every standpoint the convention was a marked success and its management functioned smoothly and efficiently in every detail. The responsibility for the conduct of the convention rested entirely with the local committee and its successful outcome reflects the highest credit upon that committee and its various subcommittees whose efficient handling of their respective functions won universal commendation.

MONDAY, FEBRUARY 4th

Monday morning was devoted to the registration of members and guests and to various committee meetings. The first Technical session was called to order on Monday afternoon at 2 p. m. by President Ryan who, after a few words of welcome, turned the meeting over to F. G. Baum, chairman of the Transmission and Distribution Committee, who presided. The following papers were then presented in abstract by their authors: *Economics and Limitations of the Super Transmission System*, by Percy H. Thomas; *Some Theoretical Considerations of Power Transmission*, by C. L. Fortescue and C. F. Wagner; *Power Transmission*, by F. C. Hanker; *Power Limitations of Transmission Systems*, by R. D. Evans and H. K. Sels; *Experimental Analysis of the Stability and Power Limitations of Transmission Systems*, by R. D. Evans; *Limitations of Output of a Power System Involving Long Transmission Lines*, by E. B. Shand.

The discussion which followed was taken part in by Messrs. C. L. Fortescue, Edward L. Moreland, V. Bush, R. D. Booth, H. Goodwin, Jr., A. E. Silver, Miss Edith Clark, R. E. Doherty, T. A. Worcester, H. R. Summerhayes, V. Karapetoff, F. W. Peek, Jr., R. D. Evans, F. E. Terman and E. A. Smith.

FORTIETH ANNIVERSARY CELEBRATION

Monday evening was devoted to the 40th A. I. E. E. anniversary celebration and to the presentation of the Edison medal to John W. Lieb. The anniversary ceremonies consisted of three addresses by charter members of the Institute, Messrs. Elmer A. Sperry, T. Commerford Martin and Elihu Thomson, all of whom recounted many interesting events and personal reminiscences of the formative days of the Institute. The last address by Past-president John J. Carty summed up the growth and achievements of the electrical engineering profession and the advances made in the art coincidently with the 40 years life of the Institute. These addresses are published elsewhere in this issue of the JOURNAL.

PRESENTATION OF THE EDISON MEDAL

Immediately following the 40th anniversary celebration, the presentation of the Edison Medal to John W. Lieb took place. President Ryan presided and first called upon Secretary Hutchinson to tell about the Edison Medal and the duty of the Institute in reference thereto.

Secretary Hutchinson then outlined the history of the Edison Medal which was founded by a group of associates and friends of Thomas A. Edison who desired to commemorate the achievements of a quarter of a century in the art of electric lighting. It was decided that the most effective way of accomplishing this object was by the establishment of a medal, which would serve as an incentive to engineers and scientists to maintain by their works the high standard of accomplishment set forth by the illustrious man whose name the medal bears.

The American Institute of Electrical Engineers was invited to accept the responsibility of making the awards and these awards are made annually by the Edison Medal Committee, consisting of twenty-four members.

The medal was first awarded in 1909 to Dr. Elihu Thomson and the other awards in order have been made to Frank Julian Sprague, George Westinghouse, William Stanley, Charles F. Brush, Alexander Graham Bell, Nikola Tesla, John J. Carty, Benjamin G. Lamme, W. L. R. Emmet, Michael Pupin, Cummings C. Chesney, Robert A. Millikan and John W. Lieb.

President Ryan then called upon Mr. Samuel Insull to tell of the life and professional career of Mr. John W. Lieb, to whom the medal was to be presented.

John W. Lieb was born in Newark, New Jersey, February 12, 1860. He was granted a mechanical engineering degree in 1880 by the Stevens Institute of Technology, an honorary degree as a doctor of engineering in 1921. He connected himself with the Brush Electric Company of Cleveland in 1880 and a year later joined the engineering department of the old Edison Electric Lighting Company. In 1882, Mr. Lieb entered upon some experimental work directly under Mr. Edison, which resulted in his becoming the electrician of the old Edison Electric Illuminating Company of New York.

Mr. Lieb was connected with the designing and construction of the old Pearl Street Station and in this way his work came under the personal observation of Mr. Edison. This resulted in his being sent to Milan, Italy to establish the first Edison Station in Europe.

In 1894, he returned to New York and became assistant to the Vice President of the Edison Electric Illuminating Co. of New York, later becoming Vice President and General Manager, occupying a similar position in the New York Edison Co., and

is today the chief executive officer of this and the affiliated companies.

The Edison Medal was conferred upon Mr. Lieb for his achievements in connection with the development of the manufacture and distribution of electrical energy, especially as applied to the incandescent lamp.

Mr. Lieb has been honored by the Kingdom of Italy, by his Alma Mater and by numerous engineering societies. He is an honorary member of various Italian and British Societies and is Chairman of innumerable committees of technical organizations. He is also a lecturer and author and distinguished himself during the war for his service in matters where the gas and electric business and the conservation and obtaining of fuel and various chemical products involved governmental supervision.

Mr. Insull then introduced Mr. Lieb and President Ryan presented the Edison Medal for his meritorious achievements in the development and operation of electrical central stations for illumination and power.

Mr. Lieb in accepting the medal said:

ADDRESS OF JOHN W. LIEB

Mr. President, Mr. Insull, Fellow Members, Ladies and Gentlemen:

I am deeply appreciative of the distinguished honor which the American Institute of Electrical Engineers, through the Edison Medal Committee, has conferred on me, in its award of the Edison Medal, and which—Mr. Insull—I have particular pleasure in accepting at your hands.

To receive this medal is indeed a consummation which any man may look upon with pardonable pride, one that associates his name with the galaxy of eminent men who have made such notable contributions to electrical science, and whose names are on the Institute's Honor Roll as Edison Medalists. This distinction, with which I am so highly honored, is of *particular* significance to the present recipient, linked as it is with the great name of Thomas Alva Edison, in whose service he was an humble associate and worker in the pioneer days of a great adventure, which developed into a great industry.

The early days of this budding industry are often referred to as characterized by empiricism, adherence to cut-and-try processes, a blind groping in the dark, through experimentation and trial.

While there is an element of truth in this concept of the methods, followed by those who developed the electrical industries in their early stages, yet it must be emphasized that, with all, it was a period when keenest analytical processes and insight were necessary to overcome the lack of past experience and developed theory. All available scientific resources, theoretical as well as experimental, had to be drawn upon to solve the stupendous problems which the electrical pioneers had set for themselves.

It was a time of the most intensive application, of untiring pursuit of the goal, when the eight hour day had not yet loomed on the horizon, when every bit of known theory or engineering experience, all the available knowledge of physics and of chemistry were applied to the solution of the problems immediately in hand, for of precedent, there was none to light the way of progress.

But a careful study of the advances made in these early years of the electrical industry will show that never in any previous epoch was there such a group manifestation of brilliant genius, of splendid vision, of indomitable perseverance, such as characterized the early workers in the fields of electrical science, and they made good use of every bit of information extant in the storehouse of human knowledge and experience.

The electrical industries differ from the other great industries of today, in that they are the children of the research laboratory. Most of the other industries of a technical character have grown up as an art, or a body of past experience. The steam engine, for instance, did not find its origin in a laboratory, nor was its early development based upon a foundation of scientific research and theoretical analysis.

When the steam engine first came into existence, heat was regarded as "caloric" and the laws of thermo-dynamics were unknown. The design of the steam engine was based on inventive intuition, mechanical skill and practical experience alone. And so it was with the steam boiler, the locomotive, the steamship, and the working of iron and steel. Similarly, the technical developments in other great branches of industry, agriculture, mining, the textile industries, etc., were such as had grown up around the practical experience, often of ages past, and were not based on well-known physical or chemical laws, which had been worked out through the inventive processes of laboratory research. The scientific background for these has come as a later manifestation and has conditioned their further development rather than their basic origin.

In the case of our electrical industries the science preceded the art and the technology. Electricity was something which through all the ages had manifested itself to mankind, only through the apalling and terrifying phenomena of lighting. Until the time of the illustrious Franklin, lighting was not identified as bearing any relation to the puny phenomena produced by frictional processes in the laboratories of the eighteenth century. It was the work of the scientists in their laboratories which made manifest to the world the very existence of electricity, and which developed the laws, interrelationships and application of electric force and energy.

The solid foundation of electrical science and theory, laid by Galvani, Volta, Oersted, Ampere, Joule, Gauss, Ohm, Faraday, Maxwell, Henry, Kelvin, Helmholtz, and Hertz, provided a firm base for the stupendous structure which was reared upon it in the years which followed, and which has brought to mankind some of the noblest contributions to the convenience, happiness and enjoyment of life.

We are engaged in the pursuit of a branch of science which was founded on profound theoretical conceptions by early investigators and experimentors, knowledge of whose fundamental laws had been the product largely of abstract scientific research which soon, however, developed into intensely practical applications in industry and the arts, until today we have throughout all the industries based on electrical science, the most remarkable fusion of theory and practice, of research and experimentation, of mathematical predetermination and concrete mechanical production, to be found in the whole realm of scientific development.

To name the recipients of the Edison Medal, conferred by the Institute, is to pass in review the milestones of the electrical industries in this country, pillars of the stupendous edifice, upon which the splendid superstructure of American electrical science, and of the electrical industries developed therefrom, has been built.

As the fields of electrical application broadened, as new industries arose and gave evidence of stability, vigor, and prosperity, it was in these electrical industries that there soon developed the largest appreciation of the value of scientific research and investigation, and the importance of the most searching mathematical analysis and experimental determination of all the factors entering into the problem of engineering development and industrial production. In no branch of science does there exist such a splendid theoretical and analytical foundation, developed for us by a score or more of brilliant minds, and in none is there made a larger use of the tools provided by exhaustive research, scientific investigation and courageous initiative. It is a commonplace to enlarge upon the discoveries in electrical science which the future may bring forth, of the marvels not yet disclosed, of the vast fields as yet untouched.

For the pursuit of all of these we have the most solid foundation, the keenest investigatory spirit, the readiness to publish and exchange acquired knowledge and information, and best of all, a splendid readiness on the part of those charged with the commercial administration of the electrical industries to spend in the broadest and most liberal spirit, the necessary funds for the erection and endowment of research laboratories, the conduct of purely scientific investigations without aim at immediate commercial results, and readiness to try out experimentally on a commercial scale, apparatus or processes which give promise of successful development.

This desire to promote scientific research knows no national boundaries, and we see one of our great manufacturing companies supporting scientific research and investigation in foreign lands, and one of our great philanthropic enterprises cooperating in the establishment abroad of laboratories for research in the ultimate constitution of matter.

With such a splendid, even though very recent history, with an enthusiastic band of energetic workers, with industrial leaders keenly alive to the advantages which the pursuit of scientific methods means to industry, who can foretell the brilliant future in store for electrical science and its practical applications. In this march of progress, the membership of our beloved Institute will surely have a leading participation.

I wish again to express my heartfelt appreciation of the great honor which the Institute has this day conferred upon me in the bestowal of this—one of its coveted awards—the Edison Medal.

TUESDAY FEBRUARY 5TH

A technical session was held Tuesday morning at which Mr. F. W. Peek, Jr., chairman of the Electrophysics committee presided. The following papers were presented in abstract: *Gaseous Ionization in Built-Up Insulation-II*, by J. B. Whitehead; *Overdamped Condenser Oscillations*, by Charles P. Steinmetz; *Free Convection of Heat in Gases and Liquids-II*, by C. W. Rice; *The Magnetic Properties of the Ternary Alloys*, by T. D. Yensen; and *Alkali Vapor Detector Tubes*, by H. A. Brown and C. T. Knipp.

These papers were discussed by Messrs. F. M. Farmer, Everett S. Lee, W. A. Del Mar, V. Montsinger, Thomas Spooner, P. L. Alger, C. L. Dawes, Alex. Nyman, Herman Halperin, H. L. Curtis, J. C. Lincoln, R. E. Doherty, A. H. Babcock, G. D. Robinson and M. G. Newman.

TRANSPORTATION MEETINGS

The subject of railroad problems was discussed Tuesday at an afternoon session and also at an evening session held in the Metropolitan Opera House. The afternoon session, presided over by N. W. Storer, chairman of the Traction and Transportation committee, consisted of an open discussion on "Operating Aspects of Railroad Transportation." The speakers were

Messrs. L. G. Coleman, Boston & Maine R. R.; L. C. Fritch, vice-president Chicago, Rock Island & Pacific R. R.; A. H. Babcock, Southern Pacific R. R.; William S. Murray; William Elmer, Pennsylvania R. R.; and N. D. Ballantine, Seaboard Airline.

The discussion at this session will be published in a future issue of the JOURNAL.

In the evening, before an audience that comfortably filled the Metropolitan Opera House, a series of addresses was given by men prominent in railway, industrial and financial circles. Arrangements were made whereby the addresses were broadcast nation-wide from several radio stations. The speakers and their topics are as follows:

The Place of Transportation in Civilization, by E. G. Buckland, vice-president New York, New Haven and Hartford R. R. *Credit Question in Transportation*, by Francis H. Sisson, vice-president Guaranty Trust Company of New York. *Transportation and the Rural Situation*, by Ralph Budd, President Great Northern R. R. *The Public's Transportation Problem*, by H. B. Thayer, President American Telephone and Telegraph Co. *Solid Foundations for Better and Cheaper Transporation*, by A. J. County, vice-president Pennsylvania R. R.

WEDNESDAY, FEBRUARY 6th

On Wednesday morning two sessions were held in parallel, Session A being devoted to industrial power subjects and Session B to electrical machinery. H. D. James, chairman of the Industrial Power Committee, presided over Session A, at which the following papers were presented in abstract:

Transient Performance of Electric Elevators, by David Lindquist and E. W. Yearsley; *Variable Voltage Control Systems as Applied to Elevators*, by E. M. Bouton; *A Novel Alternating-Current Voltmeter*, by L. T. Wilson; *Oscillographic Study of Voltage and Current in Permeameter Circuit*, by W. B. Kouwenhoven and T. L. Berry, Jr., and *Power Plant Auxiliaries and Their Relation to Heat Balance*, by A. L. Penniman, Jr.

These were discussed by Messrs. K. L. Hanson, E. M. Clayton, W. F. Ames, M. A. Whiting, J. J. Matson, Bassett Jones, A. A. Gazda, W. L. Atkinson, L. D. Jones, D. Lindquist, R. S. Glasgow and G. D. Robinson.

Session B was presided over by W. J. Foster, of the Electric Machinery Committee and the papers abstracted were as follows:

Shaft Currents in Electric Machines, by P. L. Alger and H. W. Samson; *Eddy Current Losses in Armature Conductors*, by R. E. Gilman; *Tooth Pulsations in Rotating Machines*, by T. Spooner and *Surface Iron Losses with References to Laminated Materials*, by T. Spooner. These papers were discussed by W. F. Dawson, G. E. Luke, F. D. Newbury, A. M. Perry, James Burke, R. F. Franklin, C. W. Ricker, R. B. Williamson, S. L. Henderson, T. Spooner and P. L. Alger.

DEDICATION OF THE MOORE SCHOOL OF ELECTRICAL ENGINEERING

On Wednesday afternoon a large delegation of Institute members and guests attended the dedication of the Moore School of Electrical Engineering at the University of Pennsylvania.

Dr. Josiah H. Penniman, who presided, introduced George Stevenson, a lifelong friend of Alfred Fitler Moore. Mr. Stevenson presented a portrait of the late Mr. Moore, giving a short review of his life and the reasons that impelled the trustees of his will to merge the Moore School with the University of Pennsylvania.

After a brief tribute to the memory of Woodrow Wilson, Dr. Penniman accepted, on behalf of the University, the portrait of Mr. Moore and expressed his gratitude for the generosity which resulted in the enrichment of that seat of learning.

Dr. Penniman then introduced Herbert T. Herr, graduate of Yale University and Vice-President of the Westinghouse Electric and Manufacturing Co., who spoke on "The Electrical Engineer and His Relation to the Progress of the World."

This was followed by an address by Dr. Arthur M. Greene, Jr., Dean of the Engineering School at Princeton University on "Engineering Education—its Present State and Ideals."

Following the conclusion of Dr. Greene's address, Dr. Penniman presented honorary degrees to six distinguished engineers. Elihu Thomson, Edward Weston, Frank Julian Sprague and John Joseph Carty, all past-presidents of the American Institute of Electrical Engineers, received the degree of Doctor of Laws, in recognition of their distinguished services to the world. Robert Heywood Fernald and Harold Pender, first Dean of the Moore School, received the degree of Doctor of Science.

After the dedication ceremonies a reception was held and refreshments were served in the library of the Engineering Building.

A most interesting exhibit of electrical instruments and appliances was on view for the inspection of the visitors in the Moore School of Electrical Engineering consisting of over sixty models. These were shown through the courtesy of the Westinghouse Electric and Mfg. Co., the General Electric Company, the Weston Electrical Instrument Co., Atwater-Kent, Habirshaw Wire & Cable Co., Queen Gray Co., Victor X-Ray Corporation, Leeds & Northrup, James Biddle, Automatic Electric Co., the U. S. Bureau of Standards, the Bell Telephone Co., the Western Electric Co., the Brown Electrical Instrument Co. and the Wagner Electric Corporation.

DINNER CONFERENCE ON ENGINEERING EDUCATION

A dinner conference on engineering education was held in connection with the midwinter convention on the evening of February 6th, following the dedication exercises of the Moore School of Electrical Engineering at the University of Pennsylvania. The conference was arranged under the joint auspices of the Educational Committee of the Institute and the Society for the Promotion of Engineering Education. The aim was to further the policy of close cooperation between the national engineering societies and the S. P. E. E. in the conduct of a broad project of inquiry and development which the latter organization is now undertaking under its Board of Investigation and Coordination.

D. C. Jackson, past-president of both the organizations, and a member of the Board, presided. C. F. Scott, who has similarly served both societies as president, and is now chairman of the Board of Investigation and Coordination, spoke of the origin and objectives of the present study of engineering education. The principal address was made by W. E. Wickenden, Director of Investigations of the S. P. E. E., who outlined in some detail the work and plans of the Board. He characterized the project as essentially one of collaboration between the engineering schools, the professional societies, the industries and the agencies of public administration and social welfare, through which a far greater volume of evidence may be afforded the colleges to aid them in adapting their programs to the changing conditions in the engineering world, than any single institution could provide for itself.

He emphasized the important part in such an undertaking which should be taken by the national engineering societies and cited examples of the profound influence on educational programs and standards which had been exercised by professional bodies in the fields of law, medicine and dentistry. This obligation has been accepted by the engineering profession at large through the creation of an Advisory Council on Engineering Education, whose function it is to formulate professional ideals and standards for the guidance of educational effort. The distinguished personnel of this Council is a pledge of the soundness and high character of its findings and influence. Its membership includes:

For the A. I. E. E., Messrs. Gano Dunn and F. B. Jewett.

For the A. S. C. E., Messrs. F. C. Shenehon and J. Waldo Smith.

For the A. S. M. E., Messrs. John Lyle Harrington and F. A. Scott.

For the A. I. M. M. E. and the M. M. S. A. jointly, Messrs. Wm. Kelly and Allen H. Rogers.

Mr. Wickenden characterized the past ten years as a period of temporarily arrested development in engineering education, but found a basis for optimism in the brilliant record of the past sixty years as a whole and in the concerted efforts now being made for progress.

In the discussion which followed, the participants included C. W. Rice, Secretary of the A. S. M. E., F. B. Jewett of the Joint Council, Dean Harold Pender and Prof. Robert Fernald of the University of Pennsylvania, President C. H. Howe of Case School and Prof. V. Karapetoff of Cornell. The attendance was sixty, the representation of educators and engineers in active practise being almost equal.

LECTURE BY F. G. BAUM

On Wednesday evening Frank G. Baum, consulting engineer of San Francisco, delivered a lecture, illustrated with slides, showing the sources of water power in the United States and the potentialities of the superpower transmission system. It was shown by the slides that the great hydraulic resources are in the East, especially Pennsylvania and New York, and west of the Rocky Mountains. The Middle West was shown to be largely dependent on the East and far West for power.

On the same evening an entertainment, followed by dancing, was given in the Ballroom of the Bellevue-Stratford, at which motion pictures, vaudeville and music formed an attractive program.

THURSDAY, FEBRUARY, 7th

Parallel technical sessions were held Thursday morning Session A being devoted to electrical measuring instruments and Session B to electrical machinery. G. A. Sawin, chairman of the Instruments and Measurement Committee, presided at Session A, and the following papers were presented:

Method of Testing Current Transformers, by F. B. Silsbee. *Recent Developments in Kilovolt-Ampere Metering*, by B. H. Smith and A. R. Rutter; *Automatic Transmission of Power Readings*, by B. H. Smith and R. T. Pierce; *Quadrant Electrometer for Measurement of Dielectric Loss* by D. M. Simons and W. S. Brown. The discussion which followed was by Messrs. I. M. Stein, W. H. Pratt, R. I. Hart, written discussion by A. E. Knowlton read by R. G. Warner, Frank Magalhaes, E. D. Doyle, S. J. Rosch, H. P. Sparks, J. R. Craighead and written discussion by G. A. Sawin read by Mr. Pierce.

At Session B with W. J. Foster, of the Electrical Machinery committee presiding, the following papers were presented:

Recent Advances in the Manufacture and Testing of Static Condensers in Power Sizes, by R. Marbury; *Effect of Time and Frequency on Insulation Tests of Transformers*, by V. M. Montsinger; *Insulation Tests of Transformers as Influenced by Time and Frequency*, by F. J. Vogel and *Short Circuits of Alternating-Current Generators*, by C. M. Laffoon. These papers were discussed by Messrs. J. R. Craighead, E. K. Shelton, J. E. Shrader, C. N. Johnson, E. S. Lee, J. D. Stacy, G. D. Robinson, H. L. Curtis, V. Karapetoff, P. L. Alger, R. E. Doherty, R. F. Franklin, F. D. Newbury.

On Thursday afternoon a technical session was held, devoted to papers on electrical communication. O. B. Blackwell, chairman Telephony and Telegraphy Committee, presided and called for the presentation of the following papers:

Economic Development of Step-by-Step Automatic Telephone Equipment, by P. G. Andres; *High Quality Transmission and Reproduction of Speech and Music*, by W. H. Martin and H. Fletcher; *Function and Design of Horns for Loud Speakers*, by C. R. Hanna and Joseph Slepian, and *Certain Factors Affecting Telegraph Speed*, by H. Nyquist. Discussion followed by Messrs. H. Fletcher, V. Karapetoff, C. W. Hewlett, G. O. Squier, A. Boyajian, A. Nyman, E. W. Kellogg, P. G. Andres, J. Slepian and H. Nyquist.

DINNER DANCE

On Thursday evening the annual dinner dance was held, preceded by the President's reception. This function has become a fixed feature o our midwinter conventions, and as usual, was largely attended and greatly enjoyed. Dancing continued until a late hour.

FRIDAY, FEBRUARY 8

For the final day of the convention two morning technical sessions were scheduled in parallel. Session A was devoted to electrical communication, Chairman Blackwell presiding, and Session B to electrical machinery, with Professor Karapetoff in the chair. In Session A the following papers were presented:

Measuring Medthods for Maintaining the Transmission Efficiency of Telephone Circuits, by F. H. Best; *Radio Telephone Signaling—Low Frequency Systems*, by C. S. Demarest, Milton L. Almquist and Lewis M. Clement; *Telephone Transformers*, by W. L. Casper; *An Electrical Frequency Analyzer*, by R. L. Wegel and C. R. Moore.

These were discussed by Messrs. W. H. Harden, H. H. Nance, R. L. Simpson, E. W. Kelland, H. Fletcher, L. P. Ferris, W. L. Casper and C. R. Moore.

At Session B the papers were presented as follows: *Multiple System of Cooling Large Turbo-Generators*, by Donald Bratt; *An Experimental Study of Ventilation of Turbo-Alternators*, by C. J. Fechheimer; *Importance of Brush Mounting*, by P. C. Jones, and *Theory of Three-Circuit Transformers*, by A. Boyajian.

Discussion followed by Messrs. S. L. Henderson, Edgar Knowlton, G. E. Luke, R. B. Williamson, C. M. Laffoon, R. F. Franklin, P. D. Manbeck, P. L. Alger, P. C. Jones, W. Kalb, F. D. Newbury and Donald Bratt.

LEHIGH VALLEY TRIP

On Friday afternoon a special train took a large number of the members to the Bethlehem Steel Company where they were met by members of the Lehigh Valley Section. After a trip through two plants a dinner was served at Lehigh University where the members enjoyed addresses by President Richards of Lehigh University and President McCracken of Lafayette College.

The visiting members and guests were unanimous in their praise of the exceedingly satisfactory manner in which all activities of the convention, both technical and social, were planned and carried out.

The Board of Directors of the Institute at a meeting held during the convention, adopted a resolution expressing hearty appreciation of the effective services of the members of the Convention Committee and for the excellence of all arrangements made for the comfort and convenience of those in attendance.

The general Convention Committee consisted of W. C. L. Eglin, Chairman, Ross B. Mateer, Secretary, and Messrs. F. J. Chesterman, P. H. Chase, L. F. Deming, I. C. Forshee, G. A. Harvey, W. F. James, H. P. Liversidge, J. C. Lynch, William McClellan, L. W. W. Morrow, Harold Pender, Paul Spencer, and E. B. Tuttle.

PENNSYLVANIA RAILROAD LOCOMOTIVE EXHIBIT

Delegates to the Midwinter Convention at Philadelphia had a chance to see the latest advances made in engine design and standardization when the Pennsylvania Railroad System placed on exhibition a group of engines, embodying the latest features developed in this line.

The group consisted of five steam and two electric engines. Each locomotive was of the most highly standardized type, specially designed to produce maximum efficiency in operation and represented the last word in locomotive planning and construction. The exhibit was intended to show what is necessary in the way of electric power on a high-grade railroad, as compared with steam power on the same railroad.

One of the electric locomotives designated as Pennsylvania Class "FF-1," has the distinction of being the most powerful single-unit electric locomotive ever constructed for any railroad

in the world. It is designed for heavy, slow speed freight service and weighs 516,000 pounds. It is capable of exerting a "starting tractive effort" or straight-away pull on a level track of 140,000 pounds. At a speed of 20 miles an hour, it is capable of producing continuously, for an indefinite period, a tractive effort of 73,000 pounds.

The other electric engine "L-5," embodies the very newest features and ideas in electric locomotive planning, and its construction was completed in record time—one month. This is designed to be a general utility engine, representing a standardized type, which can be used with high efficiency and economy under almost any operating conditions and in any form of service, except switching. The construction is such that simply by a change in the gear ratios between the motor and the wheels, it can be converted from a freight to a passenger locomotive and its electrical features have been so planned that by slight changes in the control apparatus, it can be operated either with alternating or direct current. All details have been worked out with the greatest care, with a view to adopting it as the standard future type for all electric locomotives in regular road service on the Pennsylvania Railroad system. It weighs 408,000 pounds.

The five steam locomotives cover every possible requirement of steam railroad service, except switching. Two freight engines were shown, one of the class "1-1 S" and the other of the Mallet articulated type, known as Class "H C-1 s." The other three steam locomotives are for passsenger service. The first, Class "M-1," a mountain type engine, intended for through express passenger service where maximum power is required, the second class "K-4s" is of the Pacific type, built for sustained speed combined with great power, and the third, Class "G-5 s," a medium weight locomotive intended for heavy local passenger service.

In addition, there were a multiple unit electric passenger coach and a gasoline rail motor car, the latter for use on railroad branch lines when the traffic is too light to support steam service or warrant electrification.

The group of equipment represented a total investment of approximately three quarters of a million dollars.

Future Section Meetings

Cleveland.—April 24, 1924. Subject: "Economic Phases of Proper Illumination." Speaker to be announced later.

Fort Wayne.—April 17, 1924. Duemling Clini Building, 2902 Fairfield Avenue, 8:00 p. m. Subject: "Public Utilities." Speaker: Mr. R. F. Schuchardt, Vice-President, A. I. E. E.

New York Section:—On the evening of Wednesday, March 19, 1924, a meeting of the New York Section will be held jointly with the Metropolitan Sections of the A. S. M. E. and A. S. C. E. The meeting will be on the subject "City Planning and Transportation" and under the sponsorship of the A. S. C. E. Section. A definite program will be sent to the membership later.

April 16, 1924, Engineering Societies Building. Subject: "The Telephone Systems of Greater New York."

Philadelphia.—March 10, 1924. Subjects: "The Klydonograph," by Mr. J. F. Peters; "Stability of High-Voltage Transmission Lines," by Mr. C. Fortescue. Both speakers are connected with the Westinghouse Electric and Manufacturing Company.

Pittsfield.—March 13, 1924. Subject: "Type S C R Single Phase Repulsion Induction Motor" (illustrated). Speakers: Messrs. S. R. Bergman and H. R. West.

March 27, 1924. Annual Dinner.

Vancouver.—April 4, 1924. Subject: "Development of the Bridge River Project." Speaker: Mr. J. R. Read.

World Power Conference, London, June 30 to July 12

OTHER EUROPEAN CONFERENCES AND MEETINGS

The first World Power Conference will be held in London, June 30 to July 12, 1924. It is to be held at the British Empire Exhibition, Wembly, London, and is promoted by the Council of the British Electrical and Allied Manufacturer's Association, in cooperation with Technical and Scientific Institutions in Great Britain and other countries.

The Conference has been called for the purpose of discussing the technical and economic problems of power development, transmission and utilization and for promoting general interest in power development. It will consider how the industrial and scientific sources of power may be adjusted nationally and internationally.

The A. I. E. E. is officially cooperating in the World Power Conference and is represented by three of its members upon the American Committee, namely, John W. Lieb, Chairman, H. H. Barnes, Jr. and Calvert Townley. Several other members will also participate by the presentation of technical papers and a considerable number of members have indicated their intention of attending. *All other members expecting to go should notify the Secretary of the Institute at once.* The details of the technical program to be presented by the U. S. Committee are embodied in the latter part of this article.

Arrangements have been concluded with Messrs. Thos. Cook & Son and the Cunard Line whereby an allotment of choice space has been reserved for delegates, their friends and families on board the new 20,000 ton liner "Scythia." The ship will sail from New York on June 19th and from Boston the following day arriving at Liverpool June 28th. This gives a day or so in London before the opening of the Conference. It is desirable that those who wish to attend the Conference arrange to make the voyage on the "Scythia" in order to derive the greatest benefit from the journey. Applications should be made immediately to Messrs. Thos. Cook & Son.

This year being the centenary of the birth of Lord Kelvin, appropriate functions will be arranged about the 10th of July, on which occasion the Kelvin medal will be presented to Dr. Elihu Thomson, Past-President of the American Institute of Electrical Engineers.

In addition to the Conference, it will be possible to take advantage of special technical tours as well as sight-seeing tours throughout Europe. Members of the Institute who cannot attend may become members of the World Power Conference upon payment of a registration fee of ten dollars which will also entitle them to certain privileges as to publications.

The Official Tours under the auspices of the World's Power Committees of England, France, Italy, Switzerland, the Scandinavian Countries and Lapland include visits of inspection to the greatest power stations of Europe and may be briefly summarized as follows:

The British tour visiting the great work of the industrial centers at Birmingham, Sheffield, Manchester, Glasgow, Newcastle with side trips to points of historic interest, such as the Shakespeare country, Edinburgh, York, etc.

The Continental Tour: France, visiting the great power plants of Wasquehal, Comines, Lille, Jeumont Lyons, Valence, Seyssel, Bourg St. Maurice, Paris and environs and other points of historic and scenic interest. Switzerland, visiting the power stations of Chancy-Pougny, Chevres, Muhleberg, Monophase, Burglauenen, Amsteg and many of the chief resorts of the Alps. Italy, visiting the power stations of Venice, Domodossala, and the chief points of interest in Milan. Venice and Stresa.

The Scandinavian Tour: Visiting the power stations of Tysse, Aslvik Tyssedal, Notodden, Rjukan, Askim, Trollhatten, Vasteras, Uppsala, Alvkarleo. Stockholm, and many cities and points of historic and scenic interest. This Tour offers a special extension to the Power Stations of Lapland and other Scandinavian points.

The program of the American Committee following is tentative, the formal titles of the papers and other arrangements not having been decided upon fully, in all cases. The plan of the Program Committee, consisting of John W. Lieb, Chairman,

Peter Junkersfeld and Calvert Townley, was to explain the character and extent of American power development from both construction and operation standpoints, and give opportunity for setting forth conditions under which American capital has been able to undertake this development.

Review of Power Resources

The first division of the program will give a National Review of Power Resources, Their Distribution and Utilization, by O. C. Merrill, Executive Secretary, Federal Power Commission, N. C. Grover, Chief Hydraulic Engineer, U. S. Geological Survey, and M. R. Campbell, Geologist, U. S. Geological Survey. Regional reviews will be given as follows: For the Northeastern states by John W. Lieb, Vice-President New York Edison Company; for the Central states by Samuel Insull, President Commonwealth Edison Company of Chicago, and for the Pacific states by A. H. Markwart, Vice-President Pacific Gas & Electric Company, and H. A. Barre, Executive Engineer, Southern California Edison Company.

Water Power and Fuels

The Problem of Water-Power Production will make up the second section of the program. John R. Freeman, Consulting Engineer, Providence, R. I., will give a general review of Current Practise. Henry J. Pierce, President of the Washington Irrigation and Development Company, and E. C. Bebb, Hydraulic Engineer, Federal Power Commission, will outline the Relation Between Power Development and Irrigation. A. P. Davis, Consulting Engineer, will discuss the Design and Construction of High Dams. Two authors will treat problems of water wheels, the paper on Impulse Water Wheels being given by William M. White, Manager and Chief Engineer, Allis Chalmers Manufacturing Company and the paper on Reaction Wheels by H. Birchard Taylor, Vice-President of William Cramp & Sons, Ship & Engine Building Company. Power Development on Navigable Rivers will be treated by an author to be announced later.

The section of the program devoted to the Preparation and Use of Fuels will consist of one paper by C. F. Hirshfeld, Chief of the Research Department of the Detroit Edison Company.

Steam and Electric Power

The discussion of Steam Power Production will be opened by a General Review of Current Practise prepared by Peter Junkersfeld and Geo. A. Orrok, Consulting Engineers. D. S. Jacobus, Advisory Engineer of Babcock & Wilcox Company will review Present Practise of Steam Generation in the United States, W. L. R. Emmet, Consulting Engineer General Electric Company, will write on Power from Mercury Vapor, and W. S. Monroe, of Sargent & Lundy, will present the latest development in High Pressure and Superheat, Steam Turbines and Condensing Equipment will be handled by Francis N. Hodgkinson, Chief Engineer of Westinghouse Electric & Manufacturing Company, South Philadelphia Works.

The Electrical Problems of Transmission and Distribution will be presented by three authors, B. G. Lamme, Chief Engineer, Westinghouse Electric & Manufacturing Company, who will treat the topic of Electrical Equipment for Power Stations, F. G. Baum, Consulting Engineer, who will discuss the Technical Problems of High-Tension Electric Transmission, and W. S. Murray, Consulting Engineer, who will relate the Economies of Power Development in Large Stations Interconnected Into a Single Superpower System.

Industrial Phases

The Industrial Phases of Power Utilization will be represented by three papers, one on Steel Mill Operation by B. H. Shover, Consulting Engineer, one on the Textile Industry by Charles T. Main, Consulting Engineer and the third on the Paper Industry by A. H. White, Chief Engineer, International Paper Company.

A general review of Electrochemical Progress and Processes in the United States will be given by F. A. J. FitzGerald, of the FitzGerald Laboratories of Chicago. Electric Power in Metallurgy will be discussed by an author to be announced later.

The discussion of the Power Problems of Transport will be provided in two papers, one on Railroad Electrification by Bion J. Arnold, Consulting Engineer of Chicago, and the second on Electric Ship Propulsion by an author to be announced.

Economic Phases

Under the section devoted to the Economic, Financial and Legal Phases of Power Development, Herbert Hoover, Secretary of Commerce will present the Government Policies Relating to Power Development. S. Z. Mitchell, President of the Electric Bond & Share Company, will outline the Problems of Financing Power Development in the United States, Guy E. Tripp, Chairman of the Board of the Westinghouse Electric & Manufacturing Company, will give the Relation of Power Development to Industrial and Economic Progress. Owen D. Young, Chairman of the Board, General Electric Company, will present the International Viewpoint on Power Development, and Carl D. Jackson, Former President of the National Association of Railway and Utilities Commissioners, will relate the Policy and Practise in the United States in Public Regulation of Public Utilities. An author to be announced later will discuss Private Versus Public Ownership and Operation.

The Relation of Power Application to Public Welfare and Industrial Expansion is the general intent of the subject of a paper by Julius Barnes, President of the United States Chamber of Commerce, which will be given in the general section of the program. This section will also contain papers by E. W. Rice, Jr., Honorary Chairman of the Board of the General Electric Company, who will point out New Fields for the Application of Power, and Arthur E. Kennelly, Professor of Electrical Engineering at Harvard University and Massachusetts Institute of Technology, who will tell of Progress in International Standardization in the Power Field. The fourth paper in this section will treat of the Relation of Power Development to Labor by an author to be announced at a later date. F. H. Shepherd, W. B. Potter and L. B. Stillwell will participate by discussion of Railroad Electrification and H. I. Harriman will discuss the Relations of Power Development to Industrial and Economic Progress.

It is hoped that the papers to be submitted at the Conference will be printed and distributed sufficiently early to allow their study prior to the opening of the Conference. Papers will not be read in full but the sessions will be devoted to oral discussion of the subjects with which they deal.

ENGINEERING SOCIETY MEETINGS

Following the World Power Conference various other meetings, excursions, and other events are being arranged by the leading professional engineering societies of Great Britain.

The Institution of Electrical Engineers, in a letter dated London, February 8, to the Secretary of the Ameridan Institute of Electrical Engineers, extends "a very cordial invitation to a party of American electrical engineers and their ladies to visit England next July and take part in the functions indicated in the following tentative program."

Visit of Electrical Engineers, 1924

TENTATIVE PROGRAM

Thursday, 10th July

a. m. Attend session of World Power Conference at the British Empire Exhibition, Wembly.
1.00 p. m. Lunch at Exhibition.
4.30 p. m. Kelvin Centenary Oration by Sir J. J. Thomson.

Friday, 11th July

a. m. Free (for visiting British Empire Exhibition, if desired).
4.30 p. m. Presentation of Kelvin Medal to Professor Elihu Thomson at Institution of Civil Engineers.
p. m. Kelvin Centenary Banquet at Connaught Rooms —Lord Balfour in the Chair.

Saturday, 12th July

a. m. Train to Cambridge.
1.00 p. m. Lunch at one of the Colleges.
p. m. Visit one or two colleges.
Garden Party or other Reception.
Train to London.

Sunday, 13th July

Special seats will be reserved for the visitors at the principal services at Westminster Abbey and St. Paul's Cathedral.
A limited number of tickets of admission to the Zoological Society's gardens during the afternoon will be available.

Monday, 14th July

a. m. Train to Birmingham.
1.00 p. m. Lunch at Birmingham.
Visits to:—
(a) Birmingham University Engineering Laboratories.
(b) Nechells Power Station of Birmingham Corporation.
(c) Stratford-on-Avon.
and/or
(d) Kenilworth Castle.
p. m. Return to London by special train (dine on train).

Tuesday, 15th July

a. m. Visit to Underground Railways.

p. m. Lunch by invitation of Underground Railways. Drive to Windsor.

Conversazione at the Institution of Civil Engineers by invitation of the Councils of the Institutions of Civil, Mechanical, and Electrical Engineers.

NOTE:—The Annual Conversazione of the Institution of Electrical Engineers will be held at the Natural History Museum, South Kensington, from 8.30 to 11 p. m., on Thursday, June 26th, 1924, the Centenary of the birth of Lord Kelvin Any of the visitors from America who may happen to be in London on that date are requested to send their names to the Secretary, P. F. Rowell, Esq., Savoy Place, Victoria Embankment, London, W. C. 2, in order that an invitation to this function may be sent to them.

The Institution of Civil Engineers has also extended to the members of the American engineering societies a cordial invitation to make use of the facilities a their headquarters, in Great George Street, Westminster, during their visit to London.

MEETINGS IN CZECHOSLOVAKIA IN JULY

The A. I. E. E. has received a letter from the President of the Electrochemical Association of Czechoslovakia, extending a cordial invitation to all members of the A. I. E. E. to attend the Sixth Annual Meeting of that organization to be held at Prague, July 18-22, 1924. At this meeting various questions of interest to electrical engineers will be discussed, and official tours will be arranged following the meeting.

An invitation to a Conference on Management to be held in Czechoslovakia, in July, has been extended to American engineers in a communication from Masyrk Academy to the American Engineering Council, and referred to the various national engineering societies. The meeting is being sponsored by the Czechoslovakian Society of Engineers and Architects, under the auspices of the Czechoslovakian Government. Management problems in manufacturing and allied pursuits will be the general topic of discussion.

The work of arranging a program of papers and supervising American participation in the congress has been delegated to the five American organizations most active in management matters, namely, the Taylor Society, the Society of Industrial Engineers, the American Management Association, the National Association of Cost Accountants, and the Management Division of the A. S. M. E. Each of these five organizations has been requested to appoint a representative upon a joint committee to plan American participation.

Engineers Hear Plan to Mobilize Industry in War

Over eight hundred members of the engineering societies cooperating with the War Department representing the New York sections of the Army Ordnance Association, the A. S. C. E., the A. I. M. E., the A. S. M. E., the A. I. E. E. and the S. A. E. assembled at the Hotel Commodore on Tuesday evening, February 5, at a dinner, after which a program for the rapid mobilization of the nation's industries in the event of emergency was explained and discussed. The purpose of this gathering was to bring the War Department's plans for mobilization of materials, as well as men, directly to the engineering profession as a means of speeding up production. It was the general tone of the meeting that industrial mobilization plans were not militaristic but were to be regarded as the best insurance against war.

Judge Elbert H. Gary, Chairman of the Board, United States Steel Corporation, presided. The speakers were the Honorable Dwight F. Davis, Assistant Secretary of War, General John J. Carty, Vice President of the American Telephone and Telegraph Company and Past President of the American Institute of Electrical Engineers, and Colonel James L. Walsh, Chief of the New York Ordnance District.

Judge Gary read the following telegram from the President of the United States:

> I have just received a telegram informing me concerning the gathering of Engineers tonight to hear the Assistant Secretary of War, Mr. Davis, discuss Industrial Preparedness as an Insurance Against War. I am glad to know that the engineers, who, in such a matter, can make one of the very greatest of possible contributions, are so deeply interested and prepared to cooperate. There can be no doubt that Secretary Davis' message presents a practical and highly constructive proposal which looks to the insurance of peace.
>
> (Signed) CALVIN COOLIDGE.

Judge Gary said in part:

> The people of the United States love peace and abhor war. They seek no quarrels and they desire no territory or extension of power beyond the confines of their country. They will submit to many things that are unreasonable and some that seem unconscionable, but that kind of a man, if aroused to duty in defense of this country, is most to be feared, because he is most terrible in a war that is forced upon him.
>
> Every intelligent man knows that the way to win a war (and, more than that, the way to prevent war) is to prepare for war if it is forced upon a country, and no one understands that better than the men who are connected with the engineering departments of industrial life.
>
> The army and navy have a right to demand of us that we shall do our part to furnish them with military necessities in time of war.

Assistant Secretary of War Davis outlined a plan for cooperation between industries and the Government in preparing for war. Describing the Government survey now going on throughout the country to determine just what industrial resources might be counted on in time of war, he said that in preparation for such an emergency the country had been divided into fourteen procurement districts for the rapid production and distribution of war material.

Mr. Davis said further:

> Our manpower plans are based, not upon a large professional army, but upon a citizen soldiery, which will come into service in time of need, and when the emergency is over, will go back into civil life. Our industrial mobilization plans are fundamentally democratic. Unless they have the whole-hearted support of the entire people, they cannot possibly succeed.
>
> Every one, every man and woman, every industry, every profession, must do its part in carrying out these plans, if they are to succeed. Capital and labor must work together. We are determined that if this country is ever again forced into war, there must be no slackers and no profiteers!
>
> We learned in the last war, that National Preparedness does not consist solely in the number of men which a nation can mobilize, train and put on the firing line. It consists also in putting in their hands, weapons which are at least equal in size and quantity and efficiency with those possessed by the enemy.

Stating that a complete study had been made to determine the needs of the army as it would be mobilized in case of war, he illustrated the complexity of the problem by the statement that a modern army needs some 700,000 different items in varying quantities at varying times. A standardized form of contract has been prepared to facilitate getting manufacturers started in the rapid production of war materials. In the event of an emergency:

> Telegrams would radiate from my office to the fourteen procurement districts; from them to the 10,000 plants all over the country, which would be required to do war work. Each manufacturer could go to his safe; take out his production schedule, plans and specifications for the articles that he was to produce; take his standardized form of contract, sign on the dotted line, and the next day begin work.

General Carty, the next speaker, called attention to the fact that in 1916 the President of the United States had written him as President of the American Institute of Electrical Engineers, asking the electrical engineers to aid in preparations for national defense. In part, he quoted as follows from the call sent in 1916 to all of the membership of the American Institute of Electrical Engineers:

> Within the next thirty days, you, as a member of the Institute, may be called upon to perform a patriotic national service of the greatest importance. At the direct request of the President of the United States, the governing bodies of the great American engineering societies have pledged the cooperation and individual effort of their members to the end that there may be made a careful industrial inventory of this country's manufacturing and producing resources for the purpose of national defense.

The value of our completed work will be incalculable. No other such national opportunity for patriotic service has ever before been accorded to the technical men of this country. Answering this call by the President of the United States, the governing body of our society has confidently pledged you to this wholly patriotic work.

General Carty further said:

We are not gathered here to advocate war, for we detest war. The industries of America desire nothing so much as they desire peace. But they have learned that if our country is kept at all times prepared to resist unjust aggression, then we have a most powerful insurance against attack—a most potent preparation for peace.

From the earliest times, the work of the engineer has been to lighten the labors of man and to provide him with agencies for the advancement of the arts of peace. That these peaceful agencies are convertible into deadly engines of war is one of the great lessons of the late conflict. Few, indeed, are the products of American industries which, in a major emergency, would not be classed as munitions of war. We are here concerned, therefore, not with that relatively small number of industries devoted to the manufacture of guns and ammunition; but the problem which we are discussing tonight affects directly every factory in the land.... Peace is not to be obtained by prohibiting the development of agencies because they can be employed for the purposes of war. We must be prepared, so that these and perhaps even greater agencies yet to be discovered, shall not be employed against us, to our own destruction.

After discussing the standard contract and form of cost accounting which was being developed, General Carty suggested that without waiting to hear formally from anybody at Washington, each industry communicate with the Assistant Secretary of War, and begin immediately a study of what will be required. He said:

Such a study has already been undertaken in the telephone industry, at the request of our Government. By direction of Mr. H. B. Thayer, the President of my company, I am now at work upon the subject with the authorities at Washington, and the Western Electric Company, which is the manufacturing branch of the Bell System, is cooperating actively with a view to determine as definitely as possible in advance the probable emergency demands of the army and the navy....

In conclusion he said:

We may not hope by any degree of preparedness, however wisely we may plan, wholly to avoid the serious losses which would fall upon all of the industries in the event that our country were again plunged into a great war. But we may hope, and we may confidently assert, that if American industries are adequately prepared to support our Government in upholding the integrity of American institutions, we have done one of the things needful to preserving the peace of the world.

Colonel James L. Walsh, describing some of the technical advances since the close of the world war, said that caterpillar tractors have been developed with a speed of thirty miles an hour as compared with a maximum of twelve miles an hour obtainable during the late war. These tractors will negotiate a 45-degree grade and will go through water up to the driver's chin.

Our own Ordnance Department has designed a 75-millimeter gun with twice the range of the French 75 used in 1918, he continued. The redesigned 155-millimeter gun outranges the French G. P. F. by nearly five miles, while the new 4.7 gun outranges our own pre-war design two and a half times and fires a heavy projectile at that.

Newly perfected automatic shoulder rifles bid fair to replace the magazine rifle of World War days. The .50 calibre super-machine gun recently developed shoots a bullet weighing four times as much as the .30 calibre Browning and throws it nearly three times as far.

Plans are being made to bring the War Department and the local branches of the engineering societies together in other large industrial centers. It is felt that this will bring about a better understanding by manufacturers of the War Department's emergency production program.

Nomination of Officers of New York Section for Year 1924-25.

The Executive Committee of the New York Section of the A. I. E. E. appointed a Nominating Committee on February 15th as follows: Calvert Townley, Chairman, H. A. Kidder, G. L. Knight, R. D. Parker, W. K. Vanderpoel. This Committee will receive and consider any suggestions that may be offered by any member of the Section. Nominations by petition signed by not less than ten members of the Section may also be made and should be received by the Nominating Committee or the Secretary in writing prior to March 10 on which day, as required by the Section By-laws, the Nominating Committee must place the complete list of nominees in the hands of the Secretary.

Send in your suggestions at once.

Standardization Bulletin of American Mining Congress

The Fourth National Standardization Bulletin of the American Mining Congress has just been published. The bulletin contains a comprehensive report on standardizing mining methods, practise and equipment in coal and metal mines. The following subjects are covered: timbering, drainage, underground transportation, mechanical loading, firefighting equipment, drill steel, mining and loading equipment. Copies of the bulletin may be obtained at a cost of $2.00 each by addressing the American Mining Congress, 841 Munsey Bldg., Washington, D. C.

Research Narratives

In January 1921, Engineering Foundation, of New York, began printing twice a month little leaflets entitled Research Narratives. Each contained a five-minute story of research, invention or discovery. The stories, or the materials for them, were contributed by scientists and engineers of international reputation.

The purposes were to broaden general intelligence about research in science and engineering and to increase interest. Means at disposal of the Foundation permitted mailing the Narratives only to a limited list. The editions were soon exhausted; numerous requests for back numbers could not be satisfied. Suggestions came to the Foundation that the Narratives should be collected into a book and reissued.

Believing that these Narratives would be interesting and useful to thousands of persons who have not known about them, Engineering Foundation (address 29 West 39 St., New York) is having the first fifty made into a small well bound book and offering it at fifty cents a copy.

The Narratives cover a wide range of subjects. A few titles will be suggestive: The Story of Mendelism; Electric Welding; Nitrogen, Its Capture and Utilization; Whittling Iron; A Serbian Herdsman's Contribution to Telephony; The Birth of Bakelite; The Upper Critical Score. Most of the Narratives are readable by students in the last years of good secondary schools as well as by their elders in business, industry, engineering, teaching and other vocations.

AMERICAN ENGINEERING COUNCIL

SELECTION OF REPRESENTATIVES ON EXECUTIVE BOARD

Representatives of national engineering organizations on the Executive Board of the American Engineering Council for the coming year have been chosen as follows:

American Society of Mechanical Engineers—Dean M. E. Cooley, University of Michigan; Dean A. M. Greene, Jr., Princeton; F. K. Copeland, Chicago; L. P. Alford, Fred R. Low and Major Fred J. Miller, New York.

American Institute of Electrical Engineers—Col. J. H. Finney, Washington; Prof. Dugald C. Jackson, Massachusetts Institute of Technology; C. E. Skinner, Pittsburgh; F. B. Jewett and L. F. Morehouse, New York.

M. G. Lloyd, chief of the Safety Section of the U. S. Bureau of Standards, will represent the American Society of Safety Engineers; S. H. McCrory, U. S. Bureau of Public Roads, the American Society of Agricultural Engineers, and H. E. Howe, Washington, the American Institute of Chemical Engineers.

For purposes of organization the country has been divided into eight districts, which will be represented on the Executive Board by the following:

District No. 1, Hubert E. Collins, Utica, N. Y.; District No. 2, W. H. Hoyt, Duluth, Minn.; District No. 3, C. R. Gow, Boston; District No. 4, Arthur R. Cruse, Philadelphia; District No. 5, John S. Barelli, New Orleans; District No. 6, C. M. Buck, Topeka, Kans.; District No. 7, O. H. Koch, Dallas, Tex.; District No. 8, J. C. Ralston, Spokane, Wash.

The St. Paul Engineers Club has been admitted to membership in the Council.

ENGINEERING FOUNDATION

EXTRACTS FROM REPORT FOR YEAR 1923

During the year, the Foundation printed its annual report of 120 pages and 24 Research Narratives. The annual report contained the second progress report on fatigue of metals, a report on graphitic corrosion of cast iron by J. Vipond Davies and other statements. The Narratives are going directly to many parts of the world and some of them are being reprinted in technical journals at home and abroad. A book of research stories is being prepared at the request and with the assistance of a group of directors of research in large industries. Foundations services as a clearing house and a bureau of information have continued.

Condensed Financial Statement
Calendar Year 1923

RESOURCES

Balance January 1, 1923		
Temporary investments, Gov't securities	$22,952.75	
Cash	4,069.52	$27,022.27
Income from endowment and temporary investments		28,062.64
Total resources		$55,084.91

EXPENDITURES—SUMMARY

Research projects	$ 8,583.15	
Promotion of research	7,895.80	
Administrative expenses	3,937.73	
Total for furtherance and support of research		$20,416.68
Balance January 1, 1924		$34,668.23

DETAILS OF EXPENDITURES

Salaries	$11,188.14
Sationery and printing	893.58
Miscellaneous office expenses	463.95
Traveling expenses	239.27
Equipment	15.40
Publications	2,164.19
Publicity	1,500.00
Division of Engineering, N. R. C. (balance on prior arrangement)	317.00
Investigation of Arch Dams	295.15
Highway Research, Advisory Board	1,000.00
Steam Table Research, Am. Soc. Mechanical Engineers, balance	334.00
Internal Stresses in Metals, balance	6.00
Concrete and Reinforced-Concrete Arches, Am. Soc. C. E.	1,000.00
Steel Columns for Bridges and Buildings, Am. Soc. C. E.	1,000.00
Total	$20,416.68

Funds received by Engineering Foundation and passed through its accounts for projects for which it acts as treasurer, totaled $13,500.00

REVIEW OF YEAR'S PROGRESS

A review of the activities for the year ended February 14, 1924 shows many interesting facts in connection with the work of the Foundation. In regard to its general development, a change was made by the Foundation Board in its financial practise. Engineering Foundation, as part of its war service, expended all its energies from the summer of 1916 to the end of 1917 in helping to establish the National Research Council and in aiding the Council's Engineering Committee. Its Founder and a member, each by liberal gifts, supplemented the funds available. Subsequently, the Foundation joined with its Founder Societies and the National Research Council in creating the Division of Engineering. The Foundation provided offices for the Division and appropriated substantial funds toward its support, until February 1923. This division and one of its important committees still are guests of the Foundation for offices.

The Foundation continues cooperation with the Division of Engineering and with the Research Council as a whole. Its Founder and one of its officers were of the small group whose contributions for purchase of land assured the $5,000,000 donation from the Carnegie Corporation for endowment and new building for the National Academy of Sciences and the National Research Council.

In the Spring of 1923 the Engineering Foundation received from its Founder Societies their first direct requests (with one exception) for assistance in their researches. Since then other requests have come and appropriations were made.

These endeavors to aid the Founder Societies emphasized the need for augmenting the Foundation's resources and a Committee on Endowment Increase has been appointed and will make a concentrated attempt, with the aid of the Societies' boards, to secure a million dollars before the end of 1924.

The Foundation has made appropriations for various research projects and has cooperated formally or informally in many others.

Committees have been studying and investigating the following subjects: Concrete Arches, Steel Columns, Mining Methods, Bearing Metals, Lubrication, Properties of Steam, Highway Research, Arch Dams, Internal Stresses in Metal, Marine Piling, the Fatigue of Metals, and the problems related to Welding.

UNITED ENGINEERING SOCIETY

EXTRACTS FROM THE PRESIDENT'S REPORT FOR THE YEAR 1923

1923 was a successful year with no outstanding features. Engineering Societies Building and its equipment have been well maintained and a few improvements effected. There have been requests for offices which could not be granted because the building has constantly been fully occupied.

Memberships of the Founder Societies at the end of 1923 totaled 54,224, and of the Associate Societies, 25,615. Consequently a total membership of nearly 80,000 have headquarters in our building.

A modern fireproof projection room for motion picture machines and stereopticons to serve the auditorium, was built during the Summer in the 4th floor elevator hall above the doors to the gallery. This improvement permitted removing from the rear gallery the inadequate temporary booth, which had displaced a number of seats and obstructed view from others.

Improvements in the Entrance Hall, changes in lighting fixtures, etc., have added to the attractiveness of the place and its use as a social rendezvous has increased. At the December meeting of the Trustees the four major wall panels were allotted to and are to be reserved for the Founder Societies severally for memorial purposes.

EXTRACT OF REPORT OF TREASURER FOR YEAR 1923

Cash Statement, Year 1923

Receipts		
Cash on hand January 1, 1923		$ 22,754.89
From Founders & Associates (library)	$128,937.49	
" Societies not in building	13,120.97	
" Various Accounts	40,079.28	
" Library Service Bureau	16.932.78	199,070.52
		$221,825.41
Payments		
For Operating Payroll	$ 47,974.81	
" Operating Expenses	35,974.24	
" Equipt. Repairs & Alterations	10 588.84	
" Misc. Inc. Taxes and Investments	55,259.64	
" Library Payroll and Expenses	59,262.83	209,060.36
Cash on hand January 1, 1924		$ 12,765.05
Distributed as follows:		
Operating Cash	$ 5,277.90	
Depreciation & Renewal Fund uninvested principal	3,790.49	
Engineering Foundation Fund, uninvested principal	437.58	
Library Endowment Fund, uninvested principal	307.50	
General Reserve Fund, uninvested principal	2,500.00	
John Fritz Medal Income	451.58	
	$ 12,765.05	

In addition to the above, United Engineering Society recorded on its books:

Net Income paid to Engineering Foundation Board	$ 26,643.82
Paid to banks for collection, custodial & adv. charges	545.80
Engineering Foundation Fund Gross Income	$ 27,189.62
Interest from Invested Income of Engineering Fund	$ 1,317.20
Paid to bank for collection & custodial charges	14.13
Total Interest	$ 1,331.33

Assets

Real Estate:		
Land	$540,000.00	
Building	1,369,398.28	
Equipment	33,171.16	
Founders' Preliminary Exp.	24,000.00	$1,966,569.44
Investments—Depreciation & Renewal Fund		159,339.94
Engineering Foundation Fund		502,066.05
Library Fund		93,351.25
General Reserve Fund		10,000.00
Operating Cash	$ 5,377.90	
Library Petty Cash	50.00	
Accounts Receivable	4,510.14	9,938.04
		$2,741,264.72

Liabilities

Founders' Equity in Property	1,966,569.44
Depreciation & Renewal Fund	159,339.94
Engineering Foundation Fund	502,066.05
Library Endowment Fund	93,351.25
General Reserve Fund	10,000.00
Deferred Credit	54.89
Balance in Activity Accounts	9,883.15
	$2,741,264.72

American Engineering Standards Committee

EUROPEAN STANDARDS

Numerous European Standards Committees have issued copies of electrical engineering standards and they may be seen at the office of the American Engineering Standards Committee. A brief outline follows:

Belgium.—Belgium Standards Association. Report No. 14, requirements for armoured cables, with impregnated paper insulation for high voltages.

Czechoslovakia.—Czechoslovakian Standards Society. Booklet containing information regarding electrical standardization work and standards in Czechoslovakia.

Germany.—Standards Committee of German Industry with the Union of German Electrical Engineers. An Annual Volume of over 500 pages by Fisher. The following have received the formal approval of the central body: Motors, Transformers, Meters and Insulation.

Great Britain.—British Engineering Standards Association. Control Apparatus, Insulation, Rating, Wires and Cables.

Holland.—General Committee for Standardization in the Netherlands. Cable Accessories.

Russia.—Central Electrical Soviet in Russia. Data on Electrical Standards and Rules.

Copies of the following electrical engineering standards, issued during 1923 by European standardizing bodies, have been received by the American Engineering Standards Committee. Copies of these standards can be furnished at a nominal charge, or the copies on file may be consulted at the office of the American

NEW SLIDE RULE FOR STANDARD PARTS

Attention has been called to a new slide rule for standard parts, which was recently put on the market in Switzerland and exhibited at the international standardization conference at Zurick. The danger of making mistakes in transferring standard dimensions to drawings and computations is practically eliminated and, furthermore, it is used much more quickly and conveniently than the usual tables of standard parts. A reprint, giving a picture and detailed description of this slide rule, is available upon request to the American Engineering Standards Committee, 29 W. 39th St., N. Y. C. at whose offices samples of the rule may be seen.

Addresses Wanted

A list of names of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York, N. Y.

All members are urged to notify the Institute headquarters promptly of any change in mailing or business address, thus relieving the member of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work.

1.—F. S. Douglass, Schweitzer & Conrad, Inc., 4435 Ravenswood Ave., Chicago, Ill.
2.—R. C. Elliott, Box 502, Wenatchee, Wash.
3.—W. J. Gibbons, Toko St., Rotorua, N. Z.
4.—Frank W. Griffin, Sorgel Elec. Co., 138 W. Water St., Milwaukee, Wis.
5.—Jerome S. Haas, 2011 Atlantic Ave., Atlantic City, N. J.
6.—Wm. I. Milburn, 915 Jackson St., Allentown, Pa.
7.—Henry C. Schnake, 21 E. 40th St., New York, N. Y

Swiss Industries Fair—Basle

It may be of interest to persons concerned in the commercial relations between the United States and Switzerland, to learn that we have received a notice from the Consulate of Switzerland in New York, that the Swiss Industries Fair will be held from May 17th to 27th. It has for its main object, along with the consolidation of the inland markets, the promotion and restoration of international commercial relations.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

EXTRACTS FROM ANNUAL REPORT FOR 1923

The routine work of the Library has progressed throughout the year with no unusual occurrences. During the year the officers have completed arrangements for a lending department. Ever since the foundation of the Library, there has been an insistent demand from members of the Founders Societies for the privilege of borrowing books. A few years ago arrangements were affected by which duplicate books could be lent to members, but the results would indicate that this service has not met the need, presumably because duplicates were generally the older books and those not in demand. Your Board has ever been alive to the desirability of a loan collection on a broader basis, and this year has found it possible to work out a plan whereby this may be accomplished. It is felt that if members will avail themselves freely of this service, it may be made selt-supporting as indicated by the Director's report.

With lending added to the searching, photoprinting, translating and general reference work previously done, it would seem that most of the methods through which members can be served have been put in practise.

During 1923 we have received $7,500 from the Carnegie Corporation as a part of the gift of $20,000 made several years ago. Although the Carnegie Corporation is thoroughly in sympathy with our work and is much interested in our progress, it finds it impossible to renew the appropriation for 1924. We are pleased to report, however, that relations with the Corporation are most cordial and that it will be glad to give consideration to an application from us at a later date. This loss of income creates a serious situation and will necessitate not only rigid economy but curtailment or slowing up of some of our future work.

The following financial statement for the year shows that the Library has been operated within its resources and that the Service Department, which aims to operate without profit, has carried on the work substantially at cost.

The accessions during 1923 and the stock of books on hand on 31 December are as follows:

	1 Jan.	Accessions	31 Dec.
Volumes	117,308	3,307	120,615
Pamphlets	32,419	66	32,485
Maps and plans	1,576	130	1,706
Manuscript bibliographies	3,904	0	3,904
Total	155,207	3,503	158,710

FINANCIAL STATEMENT 31 DECEMBER, 1923

Maintenance and Recataloging

Revenue		
Founder Societies		$32,000.00
National Electric Light Association		500.00
Society of Naval Architects & Marine Engineers		200.00
Carnegie Corporation		7,500.00
Endowment Fund Income (Net)		4,927.00
Miscellaneous Receipts		325.25
		$45,452.25
Expenditures		
Salaries Maintenance	$21,434.39	
Salaries, Recataloging	14,280.19	
Books	1,095.99	
Periodicals	2,651.12	
Binding	2,965.55	
Supplies & Miscellaneous	1,178.81	
Equipment	140.00	
Insurance	880.16	44,626.21
Operating balance December 31, 1923		826.04
Credit balance December 31, 1922		70.83
Credit balance December 31, 1923		$ 896.87

Service Bureau

Revenue		
Search Department	$10,364.57	
Photoprint Department	6,186.70	
Total		$16,551.27
Expenditures		
Salaries, searchers	$ 9,129.24	
Salaries, photographers	3,427.65	
Supplies, search	668.14	
Supplies, photographic	2,288.66	15,513.69
Operating balance		$ 1,037.58
Credit balance December 31, 1922	$ 143.16	
Accounts charged off and adjusted	265.40	122.24
Credit balance December 31, 1923		$ 915.34
Accounts receivable December 31, 1923	$ 1,173.23	
Note		
The Library Board at its meeting January 10, 1924, appropriated as follows from the Service Bureau Credit Balance		$ 915.34
For credit to Maintenance & Recataloging for services of the Director during 1923	$ 250.00	
For immediate replacement and purchase of needed equipment	550.00	800.00
Net Service Bureau credit balance Dec. 31, 1923		$ 115.34

The complete annual report may be obtained by applying to the Director of the Library, Engineering Societies Building, 33 West 39th St., New York.

BOOK NOTICES (January 1-31, 1924)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

EINE DARSTELLUNG DES NERNST SCHEN WARMETHEOREMS.

By Victor Fischer. Frankfurt a. M., Universitätsdruckerei Werner u. Winter, 1923. 2 pts., 9 x 6 in. paper. (Price not given).

Starting from geometric conceptions, the author aims to give a rigid presentation of the Nernst Heat Theorem and to show how it may be generalized and used for obtaining an equation of state, which will simultaneously answer for infinitely small temperatures and infinitely great pressures.

Electrical Insulation.

By W. S. Flight. Lond. & N. Y., Isaac Pitman & Sons, 1923. (Pitman's Technical Primers). 107 pp., illus., diagrs., tables, 7 x 4 in., cloth. $.85.

This book is an attempt to deal with the most important characteristics of the electrical insulating materials of commerce and to show how they can best be applied in the insulation of electrical apparatus. Absorbent, non-absorbent and liquid materials are discussed, as are also the factors that influence electric strength, the methods for testing insulation, and the insulation of high and medium voltage machinery. A bibliography is given.

Elementary Aeronautical Science.

By Ivor B. Hart and W. Laidler. Oxford, England, Clarendon Press, 1923. 288 pp., illus., diagrs., tables, 8 x 5 in., cloth. $2.75. (Gift of Oxford University Press, American Branch.)

The aim of this book is to supply an elementary scientific survey of the subject, which will require no mathematical knowledge except elementary algebra and trigonometry. It, therefore occupies a position between the popular books for general readers and the serious treatises for students with considerable mathematical knowledge. The text is based on the instruction given to aircraft apprentices of the Royal Air Force, Great Britain.

Elements of Railroad Engineering.

By William G. Raymond. 4th edition. N. Y., John Wiley & Sons; Lond., Chapman & Hall, 1923. 453 pp., illus., diagrs., maps, tables, 9 x 6 in., cloth. $4.00.

Views the railroad as an organization for the manufacture and sale of transportation, in which the arrangement of the plant is as much an item of design as are the individual machines and processes. The subject of the book is the fixed portion of a railroad plant and the principles that underly its design.

The author treats of permanent way, the locomotive and its work, railroad location, construction and betterment surveys. Subjects which are fully covered in special volumes have been treated briefly and generally, while those treated only in books similar to the present one are treated in detail. In the present edition various revisions have been made, and the chapter on rails has been practically rewritten.

Financial Engineering.

By O. B. Goldman. 2d edition. N. Y., John Wiley & Sons; Lond., Chapman & Hall, 1923. 325 pp., diagrs., tables, 9 x 6 in., cloth. $3.50.

Contents: Introduction—Fundamental financial calculations.—Basic costs and vestances.—Unit cost determination.—Determination of size system for best financial efficiency.—Determination of type and size of units.

The aim of the author is to furnish rules by which the engineer may determine the economic value of the different types of machines and installations of machinery. He endeavors to set forth the method of determining the installation which will give the greatest financial efficiency, although not necessarily the greatest mechanical efficiency. The new edition has been revised and extended.

Henley's 222 Radio Circuit Designs.

N. Y., Norman W. Henley Pub. Co., 1923. 271 pp., illus., diagrs., tables, 8 x 5 in., paper. $1.00.

These designs have been selected from the great variety in use with the idea of supplying a selection of typical circuits which will work well, and of explaining these fully, so that the novice can build them with assurance of success. Diagrams are provided for each circuit.

Industrial Management.

By Richard H. Lansburgh. N. Y., John Wiley & Sons; Lond., Chapman & Hall, 1923. 488 pp., illus., charts, tables, 9 x 6 in., cloth. $4.50.

Professor Lansburgh has aimed to present a coordinated, simple treatment of the problems, the ideals, and the methods of successful industrial management in a way that is at the same time broad and specific and which indicates the responsibilities of the factory executives to the workers, the owners, and the community. The book covers the whole field and is illustrated by examples chosen from a large variety of industries. The point of view is that of the medium-sized plant.

Industriebetriebslehre.

By E. Heidebroek. Berlin, Julius Springer, 1923. 285 pp., illus., charts, 11 x 8 in., boards. $4.20.

A thoughtful discussion of the main problems of industrial management, costing, factory organization, wages, depreciation and maintenance, with examples of cost systems for power plants and machine works. The book is not intended for beginners but for manufacturers and managers of experience who wish a connected elucidation of the broad principles of efficient management.

Manufacture of Electric Steel.

By Frank T. Sisco. N. Y., McGraw-Hill Book Co., 1924. 304 pp., illus., diagrs., tables, 9 x 6 in., cloth. $3.00.

A connected account of the manufacture of steel in the electric furnace, intended for students and also for those engaged in practise. The book describes both apparatus and methods, including the various types of furnaces, the materials, and the various processes in use, both acid and basic.

Mechanical Stoking.

By David Brownlie. Lond. & N. Y., Isaac Pitman & Sons, 1923. (Pitman's Technical Primers). 234 pp., illus., diagrs., tables, 7 x 4 in., cloth. $1.20.

Written from a severely practical point of view. After a short historical account of the beginnings of mechanical stoking, the author describes every make of stoker for stationary steam boilers which is actually on the market in Great Britain today.

Modern Electrical Theory, Supplementary Chapter 17; Structure of the Atom.

By Norman Robert Campbell. Cambridge, England, University Press, 1923. (Cambridge physical series). 161 pp., tables, 9 x 6 in., cloth. $3.50. (Gift of Macmillan Co., N. Y.)

This supplementary chapter presents in a connected narrative the development in knowledge of the atom which has occurred since the publication of "Modern Electrical Theory." A brief introduction is devoted to the earlier work, the Rutherford-Bohr atom, atomic number and isotopes, and the classification of atomic properties. Succeeding sections discuss the nucleus, the extra-nuclear electrons and the combination of atoms.

Modern Electro-Plating.

By W. E. Hughes. Lond., Henry Frowde, & Hodder & Stoughton, 1923. (Oxford Technical Publications). 160 pp., plates, tables, 10 x 6 in., cloth. $5.35. (Gift of Oxford University Press. American Branch.)

This book is not intended as a text-book but as a help to platers, chemists and engineers in search of practical, modern information on the electrodeposition of the metals of general interest in engineering. The first chapter is a general review of the subject. This is followed by chapters on theory, on the preparation of work, on the deposition process and on finishing. The various metals, iron, nickel, zinc, lead, tin, chronium and copper are then considered at length. A chapter on the structure of deposited metal, and one on recommended reading end the volume. Numerous references and bibliographies add to the value of the book.

Principle of Relativity.

By H. A. Lorentz, A. Einstein, H. Minkowski & H. Weyl. N. Y., Dodd, Mead & Co., 1923. 216 pp., diagrs., 9 x 6 in., cloth. $4.00.

A Translation of "Das Relativitätsprinzip," which appeared several years ago. The papers here collected are by some of the foremost students of the theory, and the collection is intended chiefly to exhibit the way in which the theory gradually grew under the stimulus of physical experiment.

Principles and Practice of Telephony; vol. 4, Circuit Refinements and Mechanical Switching. vol. 5, Mechanical Manual Switching.

By Jay G. Mitchell. N. Y., McGraw-Hill Book Co., 1924. 2 vols. illus., 8 x 5 in., cloth. $2.50 each.

Volume 4 discusses inter-office trunking, extra-efficient manual equipment, call distribution, two-digit mechanical switching, trunk mechanical switching and mechanical switching traffic.

Volume 5 deals with combinations, including switches; with the apparatus of semi-mechanical systems; and with the mechanical features of equipment for very heavy traffic. As in the other volumes, emphasis is placed on the principles and the apparatus actually used. The books are intended for those engaged in telephone work, who wish a knowledge of its technical principles.

A. C. Protective Systems and Gear.

By J. Henderson & C. W. Marshall. Lond. & N. Y., Isaac Pitman & Sons, 1923. 108 pp., illus., diagrs., 7 x 4 in., cloth. $.85. (Pitman's Technical Primers.)

The devices described are those originated by British engineering firms. Devices for limiting current, for automatically

disconnecting faulty apparatus, circuit-breakers, fuses and relays are described and their application to different types of apparatus explained. Chapters dealing with maintenance and testing are included, and there is a useful brief bibliography.

PULVERISED AND COLLOIDAL FUEL.

By J. T. Dunn. Lond., Ernest Benn, 1924. 197 pp., illus., 10 x 7 in., cloth. 25s.

A review of accomplishment in the use of powdered coal, intended primarily to call its possibilities to the attention of British manufacturers. The author describes the preparation of powdered coal, methods of transporting and firing, ash disposal, costs, advantages and disadvantages. Typical applications for various purposes are described. A brief account of the manufacture and properties of colloidal fuel is included.

DER RADIO AMATEUR.

By P. Lertes. Dresden u. Leipzig, Theodor Steinkopff, 1924 216 pp., illus., diagrs., tables, 9 x 6 in. paper. $1.35.

A comprehensive manual for amateurs. Section one gives in outline the physical and electrical foundations of radio communication. Sections two and three explain in detail the sending and receiving apparatus and their operation. The fourth section gives practical advice to amateur operators, and the concluding section is a brief history of the subject. An appendix of tables and other data includes a brief bibliography.

RADIOACTIVITY.

By K. Fajans. N. Y., E. P. Dutton & Co., (pref. 1922), 138 pp., diagrs., tables, 9 x 6 in., cloth. $3.50.

A translation of a German work which has passed through four editions in three years, this book is a readable volume, intended for those desiring a general account which does not call for great previous knowledge of physics and chemistry. The book should appeal to general readers who wish information about the progress made in the study of the chemical elements, as a result of radioactive investigations. It should also be of use to physicists and chemists who wish to review recent developments. Numerous bibliographic notes are included.

RAILWAY-SIGNALLING: MECHANICAL.

By F. R. Wilson. Lond. & N. Y., Isaac Pitman & Sons, 1923. (Pitman's Technical Primers). 109 pp., illus., diagrs., 7 x 4 in., cloth. $.85.

This introduction covers very clearly the practice of signalling on British railroads. The lay-out of signal systems, interlocking the connection of cross-overs and the mechanical apparatus are described, and instructions for preparing plans are given.

REFRACTORIES FOR ELECTRIC FURNACES. 2d edition. N. Y., American Electrochemical Society, 1924. 96 pp., 9 x 6 in., paper. $1.00.

A collection of papers by various experts, describing the necessary qualities of refractories for electric furnaces and the properties of the refractories available for this use. Most of these papers were presented before the Electric Furnace Association.

RESEARCH INFORMATION SURVEYS ON CORROSION OF METALS, nos. 1-3; Nickel, Aluminum, Copper.

By National Research Council. Research Information Service. Wash., D. C., National Research Council, 1923. 3 vols. in 1, 11 x 8 in., paper. $2.00.

These three bulletins review our knowledge of resistance of nickel, aluminum and copper to various chemicals. The information is definite and the authorities for the data are given in the extensive bibliographies which accompany each monograph. The work will be valuable to everyone interested in the use of these metals.

STUDIES IN THE ECONOMICS OF OVERHEAD COSTS.

By J. Maurice Clark. Chicago, Univ. of Chicago Press, 1923. 502 pp., 9 x 6 in., cloth. $4.00.

The subject of this book, Professor Clark says, may be defined as "a study of discrepancies between an ever fluctuating demand and a relatively inelastic fund of productive capacity, resulting in wastes of partial idleness, and many other economic disturbances. Unused capacity is its central theme."

In studying this question, of costs which are not traced to units of output or do not vary with output, the author attempts to utilize both the conception of cost of the cost accountant and of the economist, and to draw conclusions which will be of value to the man of business. The book is based on a course given to students of business and political economy at the University of Chicago.

TRACTION MOTOR CONTROL; DIRECT CURRENT.

By A. T. Dover. Lond., & N. Y., Isaac Pitman & Sons, 1923. (Pitman's Technical Primers.) 114 pp., illus., diagrs., 7 x 4 in., cloth. $.85.

In this book Mr. Dover, who has already published a larger work on traction motors and systems of control, provides a very elementary textbook on the control of direct-current traction motors, for the use of students. It is confined to an exposition of the principles involved in controlling electric cars, trains, and buses.

UNTERBAU.

By W. Hoyer. Berlin, Julius Springer, 1923. (Handbibliothek für Bauingenieure). 187 pp., illus., diagrs., 10 x 7 in., boards. $1.95.

The first part of this book gives a brief account of those geological, physical and chemical properties of the crust of the earth which influence tunneling, earth work and mining. This is followed by a description of the methods of excavating, with special attention to mechanical equipment. The second section treats of excavating, dams, retaining walls. The third section described the construction of railroad underpasses and channels for streams. Section four treats of tunneling. The book is intended as a concise reference book for practical use by builders and designers. A bibliography is given.

UTILIZATION OF LOW GRADE AND WASTE FUELS.

By W. Francis Goodrich. Lond., Ernest Benn, 1924. 368 pp., illus., diagrs., tables, 10 x 7 in., cloth. 42s.

Considers the possibilities of lignite, brown coal, peat, coke breeze, town refuse, wood waste and other waste material. Describes the methods of preparation, the necessary boiler and furnace equipment, machinery for briquetting. Gives some nformation on the results obtained in practise.

VALENCE AND THE STRUCTURE OF ATOMS AND MOLECULES.

By Gilbert Newton Lewis. N. Y., Chemical Catalog Co., 1923. (American Chemical Society. Monograph series). 172 pp., diagrs., tables, 9 x 6 in., cloth. $3.00.

A summary of modern views concerning the structure of the atom and the molecule and the nature of the chemical bond. The author has brought together the results obtained by chemists and physicists and united them in a connected account. The book is intended to show the present state of our knowledge and to suggest the directions in which further research is needed.

PERSONAL MENTION

F. ST. C. HARRIS is at present with the Boiler Inspection & Insurance Company, 908 Federal Building, Toronto, Canada.

GEO. SMITH is now General Manager of Roth Brothers & Co., 1400 West Adams St., Chicago, Ill.

RENE M. S. DE VITIS is now connected with Stone and Webster, Inc. of 147 Milk St., Boston, Mass.

WILLIAM J. LEWIS, JR. is now associated with the Triumph Ice Machine Company as District Engineer and Manager of the New York Office, 25 Church St., New York City.

CHARLES B. MCLEER, Fellow of the American Institute of Electrical Engineers, has been elected a Director and Vice President of the Continuous Transit Company of New York.

H. B. BARNES, Consulting Engineer of Denver, Col. has been elected Secretary and Treasurer of Colorado Insecticide Incorporated.

R. J. M. DANLEY has taken charge of the construction of a steam turbo-electric plant of the Central Georgia Power Company, Macon, Ga.

E. V. KARLSEN is now with the Consolidated Coppermines Corp. at Kimberly, Nevada, as Master Mechanic and Chief Electrician.

PAUL MOORE, formerly with the S. J. L. & P. Corporation of 349 Thesta St., Fresno, Cal., is now connected with the Pacific Telephone and Telegraph Co., at San Francisco.

W. W. Harper has resigned from the Hardsocg Mfg. Co. of Ottumwa, Iowa, and has become Research Engineer for the Zenith Radio Corp., Chicago, Ill.

O. R. Fahming is now with Thomas E. Murrey, 55 Duane St., New York City. He was formerly with D. P. Robinson & Co. of this city.

L. O. Gibson has severed connection with the Edendale Supply Co. of Los Angeles and has taken a partnership in a garage business in Ontario, California.

John E. McCarthy is now Electric Locomotive Repairman of the N. Y. N. H. & H. Railroad, Van Nest Shop, New York City.

B. T. McCormick, formerly with the English Electric Co., St. Catherines, Ontario, is now with the Wagner Electric Corp., 6400 Plymouth Avenue, St. Louis, Mo.

Paul J. Kruesi, is now President of the Southern Ferro Alloys Company, Chattanooga, Tenn. Previous to this he was associated with the American Lava Corporation of that city.

T. J. Russell, at present with the Central Hudson Gas and Electric Co., 50 Market St., Poughkeepsie, N. Y. was formerly located at 450 Whalley Ave., New Haven, Conn.

G. Francis Gray, who has been connected with The National Aniline & Chemical Co., Inc., 351 Abbott Road, Buffalo, N. Y. is now at 142 Lexington Ave., of the same city.

Robert Robertson retired from the firm of Strain & Robertson, Civil Engineers, 154 West George St., Glasgow, Scotland on December 31st, 1923.

J. A. Tennant is now in charge of The Tennant Company, Union National Bank Bldg., Houston, Texas, which concern is representing the Heine Boiler Company in the southern half of the State of Texas.

Roy R. Burnham, who has been engaged for the past four years in practise as a consulting engineer at 119 Water St., Boston, Mass., has associated himself as Treasurer with the Walworth-English-Flett Company, 100 Pearl St., Boston.

M. L. Dunn who has been formerly with Louis T. Klander, Consulting Engineer of Phildelphia, has severed his connections with that concern and is now with Day and Zimmerman, Inc., with offices in Philadelphia, Pa.

Robert C. Barton has left the service of the Southern Cities Power Company and is now with the Iowa Service Co., a subsidiary of the Continental Gas & Electric Corp., Missouri Valley, Iowa.

H. C. Blackwell has severed his connection with the Kansas City Power & Light Company and is now Vice President and General Manager of the Union Gas & Electric Company, Cincinnati, Ohio.

A. R. Blackwood has been transferred from the position of Superintendent of the Lake Coleridge Hydro Electric Power Station to that of Superintendent of the new station now being erected at Yangahao near Shannon, New Zealand.

L. P. Graner has resigned as Electrical Engineer of the Electrical Specialty Co., Stamford, Conn. and formed a connection with the Sprague Safety Control and Signal Corp., New York City.

T. J. Maitland has recently resigned from the employ of the American Telephone and Telegraph Company and accepted a position as instructor in Electrical Engineering at the University of New Hampshire.

Orville F. Long has accepted the position as Chief Engineer and Superintendent of Power and Maintenance of the Fisher Body Corporation, Memphis, Tenn. He was formerly with the Kelsey Wheel Co. of the same city.

John M. Cole of the New York Bar, formerly an assistant examiner in the U. S. Patent Office and for the past five years connected with the firm of Dunn, Goodlett and Massie, has now opened an office for the practise of patent and trademark at 36 W. 44th St., New York City.

N. D. Holmes has resigned his position as Chief Engineer of Farmingdale Steam Plant of the Central Maine Power Co. to accept a position with the New England Power Co. as Operating Superintendent of the Davis Bridge development near Readsboro, Vermont.

Obituary

Joseph Struthers, treasurer of United Engineering Society from 1911 and of Engineering Foundation from the organization of its Board in 1915, died at the French Hospital in New York, February 18, 1924. He was secretary and treasurer of the Engineers' Club of New York since 1909. He was born in New York, 58 years ago and was educated in the public schools, College of the City of New York and Columbia School of Mines. He received the degree of Ph. D. from Columbia University in 1895, where he taught from 1885-1900. Subsequently he had various engagements connected with mining and metallurgical engineering and 1918-1920 was in the Ordnance Department of the U. S. Army. He was a member of American Institute of Mining and Metallurgical Engineers, of which he was assistant editor 1903-05, assistant secretary 1906-10, editor 1906-12, a director in 1911, and secretary 1911-12.

Walter Merritt Riggs, President of the Clemson Agricultural College, South Carolina, died suddenly on January 22, 1924 while attending a meeting of the Executive Committee of the Association of Land Grant Colleges at Washington, D. C.

Dr. Riggs was born in Orangeburg, S. C. in 1873 and obtained a B. S. in electrical and mechanical engineering from the Alabama Polytechnic Institute in 1893. He was awarded an E. and M. E. in 1894 and an LL.D. by the South Carolina University in 1911.

He was an instructor in English in 1894-5 and in physics in 1895-6 at the Alabama Polytechnic Institute. In 1896 he joined the teaching staff of Clemson College as instructor in electrical and mechanical engineering and in 1901 became professor and director of the engineering department, acting as president in 1910 and finally becoming president in March, 1911. During the war Dr. Riggs was a member of the Naval Consulting Board and of the South Carolina State Council of Defence. He then became interested in vocational work with the A. E. F. as field organizer in France.

Dr. Riggs became an Associate in the A. I. E. E. in 1901 and was made a Fellow in 1913. He was president of the Southern Intercollegiate Athletic Association in 1913-15, vice president of the American Association of Agricultural Colleges and Experimental Stations in 1915, and president of the Land Grant College Engineering Association in 1918.

Henry St. Clair Putnam, consulting engineer, died at the age of sixty-one on January 30, 1924 from heart disease at the Hotel Blackstone, New York City, after an illness of five weeks. Burial was in Davenport, Iowa.

Mr. Putnam was a graduate of the Rose Polytechnic Institute, Terre Haute, Ind., where he received highest honors. He was president and valedictorian of his class and was the recipient of a special award for the highest standing in mathematics. Since that time he has also received the post graduate degrees of M. S. and E. E.

In 1886 Mr. Putnam entered the employ of the Thomson-Houston Electric Co., Lynn, Mass. The next year he was elected Treasurer and member of the Board of Directors of the Thomson-Houston Carbon Co., Freemont, Ohio. In 1891 he became associated with the Brush Carbon Co. of Cleveland and the year following Superintendent and Manager of the Southwestern Electric Light and Power Co. of Joplin, Mo. Later he was connected with the American Carbon Co., Noblesville, Ind. He then became a consulting engineer and had offices in Chicago and

Philadelphia and later was associated with Lewis B. Stillwell in New York. He was president of the Continuous Transit Company, New York and had designed a system of transportation by means of a moving platform, in part based on his own inventions, and had erected a demonstration plant of this system on a large scale in Jersey City, which operated successfully.

For eighteen years he had been Chairman of the W. C. Putnam Estate at Davenport, Iowa and had been active in the development of a valuable property which is held in trust for a museum and art gallery for that city.

Mr. Putman was a Fellow of the American Institute of Electrical Engineers, a member of the American Geographical Society, the National Geographical Society, the National Conservation Association, and of the Lawyers' Club, Engineers' Club, Railway Club of New York and Cosmos Club of Washington.

Past Section and Branch Meetings

SECTION MEETINGS

Akron.—January 23, 1924, Perkins School Auditorium. Subject: "Radio Transmitters." Speaker: Mr. R. B. Cummings, Radio Engineer, General Electric Company, Schenectady, N. Y. Attendance 400.

Atlanta.—January 31, 1924, Chamber of Commerce. Subject: "The Forecast of Population and the Public's Requirement for Telephone Service." Speaker: Mr. H. M. Keys, Southern Bell Telephone and Telegraph Company. Attendance 12.

Baltimore.—January 18, 1924, John's Hopkins University. Subject: "Vacuum Tubes" (illustrated). Speaker: Dr. A. W. Hull, of the General Electric Company. Refreshments were served. Attendance 150.

Boston.—January 17, 1924, Engineers Club. Subject: "High Voltage Cable Practice." Speaker: Mr. D. W. Roper, Commonwealth Edison Company, Chicago, Ill. Attendance 250.

Cincinnati.—January 10, 1924, Assembly Hall, Union Gas and Electric Company. Subject: "Radio and Carrier Current" (illustrated). Speaker: Mr. W. R. G. Baker, General Electric Company, Schenectady, N. Y. Attendance 130.

Cleveland.—January 24, 1923, Hotel Statler. Subject: "Remote Control of Power by the Use of Automatic Apparatus." Speaker: Mr. R. J. Wensley, of the Westinghouse Electric and Manufacturing Company. Westinghouse apparatus was used for demonstration. This was followed by a joint talk by Mr. C. E. Stewart of the General Electric Company, and Mr. F. Zogbaum of the Western Electric Company, General Electric apparatus having been used for demonstration. Attendance 110.

Denver.—January 18, 1924, University of Colorado. Joint meeting with University of Colorado Branch A. I. E. E. Subject: "Wired Wireless or Carrier Currents" (illustrated). Speaker: Mr. C. C. Jackson, Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa. Attendance 175.

Detroit-Ann Arbor.—January 29, 1924, Detroit. Subject: "Supervisory Control." Speakers: Messrs. R. J. Wensley of the Westinghouse Electric and Manufacturing Company, and F. Zogbaum of the Western Electric Company. Descriptions of the two types of apparatus which have been developed by these companies for the control of automatic substations were given. Attendance 110.

Erie.—January 15, 1924, Chamber of Commerce, Auditorium. Subject: "Vacuum Tubes in Radio." Speaker: Mr. H. M. Freeman, of the Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa. The theory and characteristics of different types of vacuum tube were shown and how they functioned under different conditions. Attendance 104.

Fort Wayne.—January 10, 1924, Central High School. Subject: "Astronomy." Speaker: Professor W. A. Cogshall, of Indiana University. Professor Cosghall was a member of the Indiana University expedition sent to Mexico to obtain photographs of the total eclipse September 1923. During his talk he described apparatus and equipment used, which had to be built on the ground. Attendance 100.

Indianapolis-Lafayette.—January 25, 1924, Lincoln Hotel, Indianapolis. Subject: "Native Life in Central Africa." Speaker: Mr. Thomas Duncan, President, Duncan Electric Manufacturing Company. Mr. Duncan related his experiences and told of his observations in connection with a trip of one year through Africa. The lecture was illustrated with lantern slides and was presented in a very entertaining manner. Attendance 40.

Ithaca.—December 20, 1923, Franklin Hall, Cornell University. Social meeting. Attendance 190.

Lehigh Valley.—January 24, 1924, Lehigh University. Subject: "Crossing Bridges and Scaling Stone Walls." Speaker: Mr. C. E. Skinner, Assistant Director of Engineering, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. Mr. Skinner's paper was a most interesting and instructive account of what engineering research has accomplished and particularly in the electrical field. Attendance 40.

Lynn.—January 16, 1924, G. E. Hall, Center Street, West Lynn. Subject: "Earth Magnetism and Electricity." The work of the Non-Magnetic Ship Carnegie. Speaker: Dr. Louis A. Bauer. Attendance 200.

January 23, 1924, G. E. Hall, Center Street, West Lynn. First local Section convention. Two papers were presented as follows: "Deep Bar Effect in Induction Motors" by Mr. George R. Prout, and "Power Losses in Cables and Dielectrics" by Mr. W. A. Tripp. Refreshments were served. Attendance 140.

February 2, 1924. Inspection trip to the Hood Rubber Company at Watertown, Mass. Visits were made to the Tire Department, the Receiving and Storage Departments, where the preliminary processes including mixing for the whole factory are carried on. Attendance 120.

Madison.—January 15, 1924, Engineering Building. Subject: "Success Through Service." Speaker: Mr. W. S. Vivian. Attendance 45.

Mexico.—December 6, 1923 and January 3, 1924, Centro de Ingenieros. Business meetings. Attendance at each meeting 18.

Philadelphia.—January 14, 1924, 1327 Spruce Street. Subject: "Recent Developments in Steam Power Plants as Typified in the Cahokia Station at St. Louis." Speaker: Colonel Peter Junkersfeld. Engineers from various utilities and operating companies took quite an active part in the discussion. Attendance 212.

Pittsburgh.—January 15, 1924. Hawaiian Room, William Penn Hotel. Subject: "The New Electrically Driven Hot Strip Mill of the West Leechburg Steel Company. Speaker: Mr. Noble Jones, Assistant General Manager. Members of the local section of the Association of Iron and Steel Electrical Engineers were invited to attend. Attendance 215.

Pittsfield.—January 17, 1924, Masonic Temple. Subject: "The Total Eclipse of the Sun January 24, 1925." Speaker: Dr. B. R. Baumgardt. The lecture dealt with a total eclipse of the sun which will take place January 24, 1925 and which will be visible from New York to Duluth. Dr. Baumgardt gave a very interesting discussion of the eclipse itself, calling attention to the fact that the observer must be in the range of the total eclipse to be able to see the corona and flames which shoot out from the surface of the sun. He explained exactly how an

eclipse can take place, the possible length of totality and many other phases of this interesting event. Attendance 750.

January 31, 1924, G. E. Auditorium. Subject: "Radio Reception." Covered by the following speakers: H. M. Towne "Control of Regenerative Receivers"; J. D. Stacy "The Design of Tuning Systems"; H. R. Bartlett "Radio and Audio Frequency Amplification"; H. M. Norton "General Principle of Reflexing." Attendance 275.

Providence.—February 1, 1924, Providence Engineering Society. Subject: "Troubles Caused by Transients upon Modern High-Voltage Inter-connected Transmission Systems." Speaker: Professor F. S. Dellenbaugh, Jr., Massachusetts Institute of Technology. . Attendance 40.

Rochester.—January 4, 1924, Rochester Engineering Society Rooms. Subject: "Development of A. C. Elevators." Speaker: Mr. E. B. Thurston, Haughton Elevator and Machine Company, Toledo, Ohio. Attendance 50.

February 1, 1924, Rochester Engineering Society Rooms. Subject: "Interconnection of New York State Electric Systems." Speaker: Mr. Emerson P. Peck, Utica Gas and Electric Company. Attendance 65.

San Francisco.—January 28, 1924, Native Sons Hall. Subject: "Telephonic Investigation of Human Speech and Audition." Speaker: Mr. George B. Thomas, Educational Director, Western Electric Company. Attendance 155.

Schenectady.—January 18, 1924, Edison Club Hall. Subject: "Some Problems of Engineering Education." Speaker: Professor Dugald C. Jackson, Massachusetts Institute of Technology. Attendance 110.

Seattle.—December 19, 1923, Engineers Club. Mr. R. H. Marriott, Radio Aid, Puget Sound Navy Yard, presented a paper covering the subjects of Radio Broadcasting, Transmission and Reception of Radio Frequency over High-Tension Power Lines and the Sodion Tube Detector, illustrated with numerous slides and chalk talks. Attendance 45.

January 22, 1924, Masonic Assembly Room, Arcade Building. Subject: "Telephonic Investigation of the Human Speech and Audition." Speaker: Mr. George B. Thomas, Educational Director, Western Electric Company. Attendance 200.

Spokane.—January 16, 1924, Davenport Hotel. Subject: "Telephonic Investigation of Human Speech and Audition." Speaker: Mr. George B. Thomas, Educational Director, Western Electric Company. Attendance 80.

Springfield, Mass.—January 21, 1924, Highland Hotel. Joint meeting with the Engineering Society of Western Massachusetts. Subject: "The Davis Bridge Dam." Speaker: Mr. A. C. Eaton, New England Power Company. The talk was illustrated with lantern slides. Attendance 160.

Toledo.—January 18, 1924, Toledo Chamber of Commerce. Subject: "Alternating Current Elevators." Speaker: Mr. E. B. Thurston, Haughton Elevator Company. Attendance 19.

Toronto.—January 18, 1924, Mining Building. Subject: "Automatic Stations and Supervisory Control Systems." Speaker: Mr. Chester Lichtenberg, General Electric Company, Schenectady, N. Y. Attendance 156.

February 1, 1924, Mining Building. Subject: "Colfax Power Station of the Duquesne Light Company, Pittsburgh." Speakers: Mr. C. E. Clark, Steam Power Engineer, and Mr. R. B. Howland, Electrical Engineer, of the Dwight P. Robinson Company, New York. Attendance 140.

Vancouver.—February 1, 1924, Metropolitan Building. Mr. S. E. M. Henderson of Toronto, Canadian Vice-President of the A. I. E. E., gave a brief address on the preesnt state of the electrical industry in Canada and the valuable work which is being carried out by the A. I. E. E. Mr. H. M. Lloyd presented a paper on "Impressions Gathered from a Recent Visit to Easterr Canada." Attendance 11.

Southern Virginia.—January 18-19, 1924, Norfolk, Va. Joint meeting of Southern Virginia Section of A. I. E. E. and Virginia Section of A. S. M. E. The meeting opened on the 18th at 2.30 p. m., at the Chamber of Commerce Building, Norfolk. Subject: "Production and Distribution." Speaker: Mr. William G. Hammerstrom, of Lynchburg. At 6.30 p. m. an informal dinner, followed by an informal discussion of the engineering activities in Norfolk and vicinity. The principal adress of the evening was giver by Captain H. S. Wilkins, Ordnance Department, U. S. A. He outlined the activities of the Ordnance Department in peace times and explained in detail the work that his particular division is doing. On the morning of the 19th an address on the subject of "Operation of Electric Railways" was given by Mr. L. B. Wickersham, of the Norfolk and Southern Railway. Total attendance 100.

Washington, D. C.—January 8, 1924, Cosmos Club Hall. Subject: "The Measurement of Phenomena of Short Duration." Speaker: Dr. Harvey L. Curtis, Bureau of Standards. Dr. Curtis showed and demonstrated one of his specially constructed oscillographs. Refreshments were served. Attendance 137.

January 22, 1924, City Club. Noon-day luncheon meeting. The Section had as its guests Major J. Franklin Bell, Engineer Commissioner of the District of Columbia, and General C. McKinley Saltzman, Chief Signal Officer, U. S. A. Major Bell addressed the Section giving a short talk of fifteen minutes. Attendance 43.

Worcester.—December 20, 1923, Worcester Polytechnic Institute. Subject: "Industrial Control and Applications Thereof" (illustrated). Speaker: Mr. William C. Yates, General Electric Company. Attendance 40.

January 24, 1924, Worcester Polytechnic Institute. Subject: "The Telephone"—An Evening of Moving Pictures. Speaker: Mr. T. L. Holmes, Western Electric Company, Boston Office. Mr. Holmes presented nine films showing Western Electric Works and the general manufacture of telephone equipment. Attendance 90.

BRANCH MEETINGS

University of Arizona.—January 8, 1924. Subject: "Distortion in Telephony" (illustrated). Speaker: Dr. Warner. Attendance 24.

California Institute of Technology.—February 6, 1924. Business meeting. Attendance 15.

University of California.—January 30, 1924. Subject: "Alternating Current Generators" (illustrated). Speaker: Mr. A. C. Jones, of the General Electric Company. Attendance 54.

Carnegie Institute of Technology.—February 13, 1924. Subject: "Carrier Frequency Communication." Speaker: Mr. H. A. Affel, of the American Telephone and Telegraph Company. Attendance 60.

Clemson College of Technology.—January 8, 1924. Two of the members of the Branch who accompanied Professor A. R. Powers on the inspection trip to Pittsburgh, Philadelphia, New York City and Schenectady gave an account of the trip. Refreshments were served. Attendance 20.

January 22, 1924. Professor A. R. Powers gave a practical talk on Radio; Transmission of power through the air discussed; Experiments on high voltage, high frequency performed. Attendance 55.

Colorado Agricultural College.—February 4, 1924. Subject: "History of Radio." Speaker: Mr. Daggett, a senior. Attendance 12.

University of Colorado.—January 18, 1924. Joint meeting with Denver Section of A. I. E. E. Subject: "Wired Wireless." Speaker: Mr. C. C. Jackson, of the Westinghouse Electric and Manufacturing Company. Following the lecture a demonstration was given with a 200,000-volt transformer illustrating the flashover of insulators. Attendance 175.

January 23, 1924. Westinghouse Night. Speakers: Mr. L. M. Cargo on "Reminiscences of George Westinghouse"; Mr. William Trudgian on "The Relation of University of Colorado Graduates With the Westinghouse Company"; Mr. R. A. Chase on "The Manufacture of Insulators"; Mr. W. H. Bullock on

"Apprentice School of the Westinghouse Company in 1905"; Mr. H. S. Sands on "Westinghouse Engineering Accomplishments During 1923." All of the speakers were representatives of the Westinghouse Company. Lantern slides were shown on "Westinghouse, the Institution." Attendance 95.

Cooper Union.—December 14, 1923. Subject: "Fundamentals in Radio Circuits." Speaker: Professor J. H. Morecroft. Attendance 150.

January 29, 1924. Demonstration of the operation of a manual telephone switchboard by the New York Telephone Company. Attendance 400.

Denver University.—January 11, 1924. Talk to new members. Dr. R. E. Nyswander gave a review of some of the papers that were presented at the convention of National Education at Cincinnati, Ohio, December, 1923. Attendance 16.

February 8, 1924. Moving picture entitled "A Trip Through the Westinghouse Plants." Attendance 41.

Drexel Institute.—January 11, 1924. Subject: "Electrical Control Devices" (illustrated). Speaker: Mr. George Diggins. The evolution of the Electric Locomotive was also shown. This showed the construction and operation of a modern electric engine. Attendance 45.

University of Iowa.—January 28, 1924. Election of officers as follows: Chairman, G. C. K. Johnson; Secretary, Clifford A. Von Hoene; Vice-Chairman, Clarence O. Sloan. Attendance 50.

February 4, 1924. Subject: "Electric Welding." Speaker: Mr. A. J. Kosban. Attendance 50.

Iowa State College.—January 16, 1924. The meeting was in charge of representatives of the Iowa Division of the Northwestern Bell Telephone Company. The operation of a telephone system was explained, by means of a miniature switchboard; a short dialogue was given on the incorrect use of the telephone. Music was also furnished. A picture showing the effect of natural weather conditions upon telephone lines was shown. Attendance 350.

January 30, 1924. Subject: "Opportunities in the Electrical Engineering Industry." Speaker: Mr. N. G. Symonds, General Manager of the Chicago office of the Westinghouse Electric and Manufacturing Company. Mr. Symonds also showed a film entitled "White Coal," which dealt with the development of water power. Attendance 250.

University of Kentucky.—January 25, 1924. Subject. "Eugenics." Speaker: Dr. W. S. Anderson. Attendance 30:

Lafayette College.—December 8, 1923. Mr. Reinecker. Superintendent of the Public Utilities Company of the Pennsylvania Power and Light Company, spoke on the relations of the Public Utilities Company to the public and how it meets the problems which arise. Attendance 20.

December 15, 1923. Mr. Bressler, Service Department of the Pennsylvania Edison Company, gave a short talk on the duties of the Service Department. Attendance 20.

January 12, 1924. Professor King gave a lecture on the control of ships by electricity. Attendance 20.

January 19, 1924. A motion picture entitled "The Queen of the Waves" (courtesy General Electric Company) was shown. Attendance 20.

University of Maine.—January 9, 1924. Subject: "Recent Developments in Railway Electrification" (illustrated). Speaker: Mr. Bearce, a former Student of the University and now employed by the General Electric Company. Attendance 94.

Marquette University.—February 7, 1924. First annual Branch banquet. Attendance 26.

School of Engineering of Milwaukee.—January 25, 1924. Subject: "Modern Application of the Electric Furnace in Industry." (illustrated). Speaker: Mr. Payne, Service Engineer of the Pittsburgh Electric Furnace Company. Attendance 47.

University of Minnesota.—January 9, 1924. Subject: "Steam Turbines and Their Development." Speaker: Mr. Douglass, General Electric Company. Attendance 95.

Montana State College.—January 15, 1924. Subject: "Opportunities With the General Electric Company." Speaker: Mr. Henry Ellingson. Attendance 92.

January 22, 1924. Four papers on "Radio" were presented by members of the senior class. Attendance 96.

January 29, 1924. A film entitled "History of the Telephone" was shown. Attendance 59.

University of Nevada.—January 30, 1924. Mr. M. M. Boring, of the Industrial Service Department of the General Electric Company, gave an interesting talk on the General Electric Organization. The main topic was regarding the employment of electrical and mechanical graduates and the instruction course given them. The talk was preceded by motion pictures of the General Electric Plants. Attendance 56.

University of North Carolina.—January 10, 1924. Subject: "Treatment for Electric Shock." Speaker: Dr. E. A. Abernathy, of the college infirmary. Attendance 43.

January 24, 1924. Mr. I. R. Alexander spoke in an entertaining and practical way on "After Graduation, What?" Mr. T. B. Smiley explained the history, development and operation of the induction integrating watthour meter, and pointed out the difference in the various types. Attendance 27.

February 7, 1924. Subject: "Transmission of Pictures by Radio." Speaker: Mr. H. L. Coe. Attendance 18.

University of North Dakota.—January 14, 1924. A two-reel picture was shown, entitled "Electrified Travelogue." Attendance 13.

Northeastern University.—January 17, 1924. Subject: "Modern Fire Alarm Systems" (illustrated). Speaker: Mr. F. A. Raymond, of the Gamewell Fire Alarm Telegraph Company. Attendance 37.

Notre Dame University.—January 25, 1924. Subject: "Automatic Telephones." Speaker: Mr. Baer, of the Automatic Electric Company, Chicago, Ill. A two-reel film entitled "The Dial of Destiny" was shown. Attendance 36.

Ohio Northern University.—January 17, 1924. Mr. Barnes gave a demonstration on wire splicing, and Mr. Goodman a talk on "Illumination." Attendance 30.

January 31, 1924. Subject: "The Fynn-Weichsel Motor." Speaker: Dean Alden. Attendance 32.

Oklahoma A. & M. College.—January 16, 1924. Election of officers as follows: Chairman, F. C. Todd; Vice-Chairman, R. F. Riddle; Secretary, R. W. Twidwell. An illustrated lecture on "The Safety Switch" was given by Mr. Harry Hoke, of Stillwater. Attendance 14.

Oregon State Agricultural College.—January 24, 1924. Subject: "Investigation of Speech" (illustrated). Speaker: Mr. George B. Thomas, Educational Director of the Western Electric Company. Attendance 200.

Pennsylvania State College.—January 28, 1924. Business meeting, followed by an interesting talk by Mr. H. O. Alexander on his summer work with the Philadelphia Electric Company. Attendance 19.

University of Pittsburgh.—January 11, 1924. Mr. J. N. Lehman spoke on current events in the electrical engineering field, and Mr. S. H. Wasilewski on "Control Systems on Street Railways." Attendance 33.

January 18, 1924. Subjects: "Mercury Vapor Turbine" and "Traffic Congestion," by Mr. A. J. Marshall; and "Life of Faraday," by Mr. W. T. Ackley. Attendance 32.

January 25, 1924. Mr. F. Wills discussed Report of meeting of Pittsburgh Section on a paper presented at that meeting, "Operation of Hot Strip Mill of West Leechburgh Steel Company." Mr. P. B. Long spoke on the following subjects: "How many Electrons for a Cent?", "City of Tulsa Pipes Water from Mountain Sixty Miles Away," "Prospects for the Engineer in 1924 Brighter." Attendance 29.

February 8, 1924. Subjects: "Ignition Systems," by Mr. C. L. Kling usmith, student; and "Qualities to be Developed in th Engineer," by Mr. C. A. Anderson, a former graduate. Attendance 26.

Rutgers College.—January 17, 1924. Subject: "Balancer Set vs. Two Generators in a Three-Wire System," by Mr. Szabo, '24; and "Several Important Points to be Considered in High-Voltage Transmission," by Mr. H. Cromley, '25. Attendance 13.

University of Southern California.—January 10, 1924. Business meeting, followed by a talk and demonstration on "Relays" by Mr. Henninger, of the Southern California Edison Company. Attendance 34.

Stanford University.—January 15, 1924. Business meeting. Attendance 17.

January 24, 1924. Subject: "The Work of the Bureau of Standards." Speaker: Mr. H. J. Walls, of the Bureau of Standards. Attendance 29.

January 29, 1924. 4:15 p. m. Subject: "Electrical Transmission and Audition of Voice Frequencies" (illustrated). Speaker: Mr. George B. Thomas, of the Western Electric Company. Attendance 65.

7:15 p. m. Subject: "The Manufacture of Telephone Cables" (illustrated). Speaker: Mr. George B. Thomas. Attendance 35.

A. and M. College of Texas.—January 25, 1924. Subjects: "Insulating Transformers," by Mr. W. J. Everett; "The Texas Traction Company," by Mr. H. S. Smith. Attendance 64.

University of Texas.—January 14, 1924. Subjects: "The History Organization and Aims of the A. I. E. E.," by Professor J. M. Bryant; "The Development of the Vacuum Tube," by Mr. J. P. Woods; "The Application of the Vacuum Tube to Radio Circuits," by Mr. R. S. Willis. Attendance 25.

February 4, 1924. Subjects: "The Manual Switchboard Exchange," by Mr. P. J. Rempe, (student); "Automatic Telephone Switching Equipment," by Professor J. W. Ramsay. Professor Ramsay illustrated his talk with a small demonstration automatic telephone set. Attendance 26.

University of Utah.—January 23, 1924. Business meeting and election of officers as follows: Chairman, I. J. Kaar; Secretary, M. B. McCullough. Attendance 17.

Virginia Polytechnic Institute.—January 30, 1924. Subject: "Concatenation of the Induction Motor." Speaker: Mr. T. L. Oliver. Attendance 44.

University of Virginia.—January 18, 1924. Joint meeting with the University of Virginia Branch of the A. S. M. E. Subject: "The Bare and Stroud Range Finder." Speaker: Professor Arthur Macconochie. Attendance 27.

University of Washington.—January 15, 1924. Subject: "Recent Development of the Skagit Project." Speaker: Mr. J. D. Ross, of the City Light Department. Attendance 39.

February 5, 1924. Election of new Chairman, Mr. N. MacEwell. A motion picture belonging to the Sangamo Electric Company was shown, depicting the process required to produce a modern electric meter. Attendance 41.

Yale University.—January 16, 1924. Subject: "Speaking Crystals and The Piezo Electric Effect" (illustrated). Speaker: Mr. A. M. Nicolson, of the Western Electric Company. Attendance 163.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers as a cooperative bureau available only to their membership, and maintained by contributions from the societies and their individual members who are directly benefited.

MEN AVAILABLE.—Brief announcements will be published without charge and will not be repeated, except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of \$3 per quarter, or \$10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of \$10 for all positions paying a salary of \$2000 or less per annum; \$10 plus one per cent of all amounts in excess of \$2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will, it is hoped, be sufficient, not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case and with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

(For other employment announcements see page 44 of the Advertising section.)

POSITIONS OPEN

HEATING ENGINEER, who has had some practical experience in testing low pressure steam and hot water cast iron boilers. Efficiency and circulation tests on warm air furnaces Only engineers with this experience will be considered. Salary \$150-\$175 a month. Location, New Jersey. R-3267.

ENGINEER, who has had accounting experience in a factory making large quantities of small devices like telephone and telegraph apparatus. Salary \$5000-\$6000 a year. Location, New York City. R-3223.

MEN AVAILABLE

ELECTRICAL ENGINEER AND EXECUTIVE of 43, married, technical education, Associate A. I. E. E. 28 years' unusually broad experience in every conceivable phase involved under the heading of "Electrical Machinery." Thorough experience in design and production from fractional to 300 kw., experienced in application, sales maintenance. Industrial and power plant design and installation. Business and factory management of large repair shop and rebuilt machinery. Wants connection with good organization who can advantageously absorb his valuable services at consistently reasonable remuneration. B-7313.

GRADUATE ELECTRICAL ENGINEER with varied executive experience, available with reasonable notice. Six years plant superintendent with large public utility. Three years on electrical equipment development, two years in responsible control. Three years plant manager of non-electrical industrial plants employing from 100 to 500 men. Age 37, present salary, \$7000. B-7386.

DEVELOPMENT ENGINEER. My line is designing and developing electrical apparatus, standardizing parts and organizing quantity production. I like problems requiring original design and inventive application. Good record, electrical graduate, age 29. What have you? B-7388.

GRADUATE ELECTRICAL ENGINEER, 24 years of age. 9 months' experience shell manufacturing, two months' experience small motor tests, sixteen months' experience switchboard design and responsible charge of drafting, wiring and factory assembly. Now employed.

Desires change of location with future for executive work and application of originality. B-6918.

ELECTRICAL ENGINEER, 1922, seeks position where proper training will lead to a promising future. Two years' general experience. New York City and vicinity preferred. B-7227.

ENGINEER-ACCOUNTANT-Licensed electrical engineer New York state. Age 33 years. Experienced in power station and industrial plant design. Training in engineering and business administration including accountancy. B-7364.

PUBLICITY ENGINEER—R. P. I. 1920. E. E. Excellent recommendations. Instructor R. P. I. since graduation. Author plays purchased by French, New York and London. Engineering reports Western Electric Company summer 1920. Production-Control Department Cluett, Peabody & Co., summer 1922. Superintendent State Street Bible School 1922 to date. B-7443.

GRADUATE ENGINEER, age 24, single, with two years' experience in distribution engineering; desires position with a power company on design and construction of power plants. Location anywhere in United States. B-7455.

GRADUATE ELECTRICAL ENGINEER, 1922, single, one year drafting room experience in electrical machine design. At present employed but would like position ultimately leading to responsible work with small manufacturing concern, or in consulting engineer's office. Capable of handling field work on construction. Prefer New York or Chicago, but willing to go elsewhere. B-7454.

DRAFTSMAN, electrical, age 27, served apprenticeship in shop: switchboard department foreman. Three years' drafting experience on central station switchboards, substation and powerhouse layout. At present employed drafting. Desires position with Eastern manufacturer, New York or New England preferred. B-7453.

ELECTRICAL ENGINEER, technical graduate with 3 years on G. E. test, 9 years on design and construction of railway and power distribution and power transmission. Experience in appraisal of electrical railway properties. Desires permanent position of responsibility with constructing and operating company. B-7456.

ELECTRICAL ENGINEER, class of 1920, desires position. 1½ years' experience in inspection and testing department of a large corporation. Two years' teaching experience in a trade school teaching contracting and construction. Several months' experience with a large publishing firm, publishing scientific magazines and books. Would like to make connection with some engineering concern. B-3781.

INSTRUCTOR OR ASSISTANT PROFESSOR in Electrical Engineering. Five years' engineering experience. Six years teaching. Age 32, married. Desires position as instructor or assistant professor in Electrical Engineering. An opportunity to do graduate work desirable but not essential. B-7463.

TECHNICAL GRADUATE, would like position on test floor of some small company, where he will get experience on all types and sizes of motors and generators. Experience consists of testing on automatic telephone. Armature winding and steel mill maintenance. B-7464.

GRADUATE M. E. and E. E. Cornell, age 40, married. Sixteen years' manufacturing and industrial experience as designing, sales and operating engineer. Member A. I. E. E. and Association of Iron and Steel Electrical Engineers. Desires permanent connection with good remuneration, and responsibility with well established industrial organization, electrical manufacturer or consulting engineer. B-6694.

RESEARCH ENGINEER, graduate University of Toulouse, France, 6 years' University course and laboratory training, 2 years' research experience, familiar with mathematics and physics, author of many inventions. Speaks many languages, single. Desires position with electrical or radio concern having broad field of activity and recognizing ability. Available on short notice. B-7178.

EXECUTIVE-SALES ENGINEER. Technical graduate desires connection in sales department of progressive manufacturing concern located in the middle west. Twelve years' experience in executive and sales work with large electrical manufacturer. B-7472.

SUPERINTENDENT of construction desires position, supervisory capacity on transmission and distribution, power or signal system. 38, 18 years' practical experience on underground conduit and cable work, steel tower and pole line construction. Can furnish 15 experienced live wire and tower linemen if desired. B-7473.

COMMERCIAL ENGINEER, for Central Station. Twelve years' experience in power plant investigations, commercial sales, installation and operation of equipment. Technical graduate. Available on short notice. B-7492.

E. E. '22 and B. S. '21 desires to change his position. 10 months' experience in the design, development and testing of radio materials, 1 years' experience as assistant engineer in large shop manufacturing automatic signal and photometric devices, 3 months' experience as production manager with manufacturer of radio, railroad and marine supplies. B-5435.

PRODUCTION ENGINEER. A young man who has been educated and experienced to correlate the viewpoint of the electrical and industrial engineer, is available for an organization manufacturing electrical equipment. Able to formulate process layouts, planning and production control. Member of A. I. E. E. and S. I. E. B-7482.

MECHANICAL AND ELECTRICAL ENGINEER, American, desires responsible position. 20 years' experience in construction, operating and maintenance of power plants and street railways. Working knowledge of Spanish, excellent references. Now employed, available 2 weeks. B-6459.

ELECTRICAL AND MECHANICAL ENGINEER, college graduate. Two years' experience in line construction and machine designing. Age 26, prefer west coast, but will consider any location. Married, expect salary of $2500 per year. B-7481.

PROFESSOR, ELECTRICAL ENGINEER—Teaching experience of ten years covers nearly all basic and specialized electrical courses. Broad experience in the industry covering construction, design and general engineering work. Desire professorship in electrical engineering. Available in September. Salary about thirty-five hundred dollars. B-7083.

YOUNG MAN, age 23, technical college graduate 1923 in E. E. Several years' business experience in retail merchandising, also some experience in municipal engineering work. Desires start in electrical engineering. Middle west preferable. B-7495.

EXECUTIVE ASSISTANT—Position desired with growing company in commercial rather than purely engineering capacity, by electrical engineer with nine years' experience since graduation. Work has covered manufacturing, design, appraisal, maintenance, and power plant operation. Past five years has been spent with one company with work on controller manufacture, design and machine design. Position as assistant to general executive preferred. A-280.

SALES ENGINEER, Yale graduate, trained in Westinghouse Apprenticeship Course at East Pittsburgh and Service Department at New York. Ten years' experience in mechanical and electrical sales, designing and contracting work in many factories producing a great variety of products. Desires connection with a thoroughly reliable company where demonstrated ability and hard work will win rapid advancement in position and salary. B-7493.

SUMMER EMPLOYMENT, Electrical engineer desires position from June 10 to Sept. 20. Construction work in New York State preferred. Experience, 3 years, instructing in junior and senior courses at Cornell, 1 year in Engineering Department of the Philadelphia Electric Co., 2 summers in the Westinghouse Branch Office at Buffalo and 1 summer in the Engineering Department of Buffalo General Electric Co. Salary $200 a month. B-7496.

TECHNICAL GRADUATE in electrical and agricultural engineering. Six years' university training. Married. Six years' practical experience distributed over fields of electrical and chemical manufacture, public utility, research and teaching. Inventive ability. Desires position in electrical or allied fields where opportunities for expansion, with commensurate returns, are good and initial salary is not less than $2100. B-7498.

ENGINEER-EXECUTIVE, technical graduate with seventeen years' successful experience in design, construction and operation of steam and hydroelectric plants and industrial properties. Ability to handle men and develop harmonious relations. At present employed, but desire to make change about May first. B-1229.

GRADUATE MECHANICAL ELECTRICAL ENGINEER. Well grounded in fundamentals and theory and reinforced with broad practical experience covering development, design, manufacturing and construction of engineering properties and equipment. Also plans, specifications, purchase, installation and operation of mechanical, electrical, hydraulic and refrigerating plants and equipment. Desires responsible position of consultative or advisory capacity with aggressive manufacturing, power or engineering concern. B-2656.

GRADUATE ENGINEER, M. E. E. E. Cornell. Associate A. I. E. E. Age 31 years, single, location immaterial. 2 years assistant to chief engineer drafting and plant testing, 6 years electrician, assistant chief engineer, acting chief engineer, construction, operation, maintenance, mechanical and electrical divisions electrified sugar factories, Cuba and Porto Rico. 1 year commission officer steam Eng. Div. U. S. N. Desires position with construction, power or consulting engineer. B-6925.

ELECTRICIAN, licensed, seven years' experience in electrical construction and maintenance. Technical education. Desires position in the engineering line. Resident of Chicago, Illinois B-7513.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED FEBRUARY 7, 1924

ABBEY, SAMUEL H., Central Station Engg. Dept., General Electric Co., Schenectady; for mail, Watertown, N. Y.

*ABBOTT, L. EMERSON, Floor Electrician, Union Gas & Electric Co., Front & Rose Sts., Newport, Ky.

ADELSTEN, KENNETH OLAI, Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

*ALBERT, RUDOLPH M., Foreman, Lord Electric Co., 105 W. 40th St., New York, N. Y.

*ALLEVATO, WILLIAM JOHN, Student, University of Southern California, Los Angeles, Calif.

ALMQUIST, CARL OSCAR, Queens Electrical Equipment Co., 86 Main St., Flushing; res., Little Neck, N. Y.

ANDERSON, BARRETT EUGENE, Substation Operator, Great Western Power Co., Berkeley, Calif.

*ANDERSON, CLAIRE A., Design & Development Engr., Supply Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.

*ANDERSON, RAYNOR G., Field Engr., Distribution Div., Engg. Dept., Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.

ANDERSON, TED C., Draftsman, Westinghouse Elec. & Mfg. Co., 2201 W. Pershing Rd., Chicago, Ill.

ANNIS, JAMES BERNARD, Foreman, Kansas City Power & Light Co., 1330 Grand Ave., Kansas City, Mo.

*APPLEMAN, FRANK CHARLES, Student, University of Minnesota, 509-15th Ave., S. E., Minneapolis, Minn.

ARONSON, SAMUEL, Electrical Draftsman, New York Edison Co., 44 E. 23rd St., New York, N. Y.

*AXMAN, BERTRAM, Student Engineer, Testing Dept., General Electric Co., Schenectady, N. Y.

BALDWIN, EDWARD NICHOLAS, Mechanical Engr., Transformer Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

BALSON, DONALD WESLEY, Testing Dept., Packard Electric Co., Warren, Ohio.

BARCLAY, ALEXANDER J., Equipment Statistician, New York Edison Co., 44 E. 23rd St., New York; res., Yonkers, N. Y.

*BARENSCHER, PAUL J., Student, University of Wisconsin, 543 State St., Madison, Wis.

*BARKER, ORLAN, Inspector, Brooklyn Edison Co., 1553 E. 14th St., Brooklyn, N. Y.

BARNES, WILLIAM A., Electrical Testing Laboratories, 80th St. & East End Ave., New York, N. Y.

BARNET, JOHN H., Valuation Dept., Portland Railway, Light & Power Co., Electric Bldg., Portland, Ore.

*BARR, JAMES RAYMOND, General Tester, New York Edison Co., 92 Vandam St., New York; res., Brooklyn, N. Y.

BAUER, RALPH G., Electrical Draughtsman, H. Koppers Co., Union Trust Bldg., Pittsburgh, Pa.

BEADLE, WALTER JAY, Traffic Engr., Philadelphia Rapid Transit Co., 59th & Callowhill Sts., Philadelphia, Pa.

BECKER, JAMES R., Materials Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

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*BELL, ADAM, Electrical Draftsman, Toronto Hydro-Electric System, Duncan St., Toronto, Ont., Can.

*BERG, SAMUEL ARNOLD, General Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.

*BERNHARDT, CARL P., Time Study, Westinghouse Elec. & Mfg. Co., 160-7th St., Brooklyn; res., Arverne, N. Y.

*BERRY, THOMAS LANSDALE, JR., Engg. Assistant, Chesapeake & Potomac Telephone Co. of Baltimore, 108 East Lexington St., Baltimore, Md.

*BEYERS, ARTHUR PAUL, Construction Foreman, Consumers Power Co., Jackson; for mail, Saginaw, Mich.

*BLANKENBUEHLER, JOHN HENRY, Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.

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BOARDMAN, RUSSELL LEONARD, Electrical Engineer, Westinghouse Elec. & Mfg. Co. East Pittsburgh; res., Wilkinsburg, Pa.

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BOHL, CLYDE, Student Engineer, Consumers Power Co., Jackson, Mich.

*BOICE, MILFORD C., Distribution Engineer, Public Service Co., 129 N. Genesee St., Waukegan, Ill.

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BONIFIELD, HERSCHEL M., Engineer, New York Telephone Co., 104 Broad St., New York, N. Y.

BOSSARD, GISBERT L., President & General Manager, Bossard Railway Signal Co., Cannon Bldg., Troy, N. Y.

*BOXER, JULIUS, Armature Winder, Washington Electric Co., 41 W. 4th St., New York, N. Y.

*BRAAM, ALFRED E., Student, School of Engineering of Milwaukee 415 Marshall St., Milwaukee, Wis.

*BRADEN, RENE ALBERT, Assistant in Electrical Engineering Dept., University of Minnesota, Minneapolis, Minn.

*BRAUN, ELMER HENRY, Automatic Control Man, Duquesne Light Co., Chamber of Commerce Bldg., Pittsburgh; res. Wilkinsburg, Pa.

*BRICKS, HARRY MAXWELL, Industrial Control Engg. Dept., General Electric Co., Bloomfield; res., East Orange, N. J.

BRISTOL, WYMAN A., Engineer, The Bell Telephone Co. of Penna., 261 N. Broad St., Philadelphia, Pa.

BROCKMEYER, EDGAR W., Chief Engineer, Master Electric Co., 1st & Sears St., Dayton, Ohio.

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*BROWN, ROSS D., Engineer, Statistical Dept., Monongahela West Penn Public Service Co., 503 Bethlehem Bldg., Fairmont, W. Va.

*BRUNING, WILLIAM H., Technical Employe, Plant Dept., American Tel. & Tel. Co., 311 W. Washington St., Chicago, Ill.

*BUBLITZ, ZENO PALMER, Student, School of Engineering of Milwaukee, Milwaukee; res., Cedarburg, Wis.

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FANTHAM, DAVID, Erecting Electrical Engineer, Canadian General Electric Co., King St., W., Toronto, res., Long Branch, Ont., Can.
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*FISCHER, HAROLD W., Northwestern Bell Telephone Co., Telephone Bldg., Minneapolis, Minn.
FISLER, CHARLES E., Checker, Engg. Dept., Adirondack Power & Light Corp., Schenectady, N. Y.
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*FORBES, BRUCE GARDNER, Electrical Designer, Stone & Webster, Inc., 147 Milk St., Boston; res., Milton, Mass.
FOSTER, W. C., Asst. Operating Engineer, Portland Railway, Light & Power Co., 622 Electric Bldg., Portland, Ore.
FOUNTAIN, HERON ALBERT, Treasurer, The Ohio Public Service Co., 1800 B. F. Keith Bldg., Cleveland, Ohio
FOWLER, HENRY ELWOOD, Electrical Draftsman, New York Edison Co., 40 E. 23rd St., New York; res., Tompkins Cove, N. Y.
FREDERICK, PAUL, Engineer, Central Station Engg. Dept., General Electric Co., Schenectady, N. Y.
FREDRIKSON, HENNING WILLIAM, New York Edison Co., 44 E. 23rd St., New York; res., Brooklyn, N. Y.
FREI, CHARLES, JR., Construction Foreman, General Electric Co., 627 Greenwich St., New York, N. Y.; res., West Hoboken, N. J.
*FREND, JOHN J., Electrician, National District Telegraph Co., 23 Perry St., New York, N. Y.; res., Jamestown, R. I.
*FUGILL, ALFRED T. PERCIVAL, General Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.
FULNER, RAY LESLIE, Asst. Equipment Engineer, Cin. & Sub. Bell Telephone Co., 225 E. 4th St., Cincinnati, Ohio.
*GADBOIS, JOHN STUART, Superintendent, Meter & Engg. Depts., Lyme Electric Power Co., Niantic, Conn.
*GARMAN, FRANK RUSSELL, Engg. Assistant, Bell Telephone Co. of Penna., 1230 Arch St., Philadelphia, Pa.
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*GEORGE, ROSCOE HENRY, Research Assistant, Engg. Experiment Sta., Purdue University, Lafayette; res., West Lafayette, Ind.
GERHART, JOSEPH JOHN, Field Electrical Engineer, Braden Copper Co., Rancagua, Chile, S. A.
*GHIRARDI, ALFRED A., Electrical Engineer, J. Livingston & Co., Grand Central Terminal, New York, N. Y.
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*GILDERSLEEVE, T. SHERMAN, Electrical Engineer, Philadelphia Electric Co., 23rd & Market Sts., Philadelphia, Pa.; res., Merchantville, N. J.
GINNA, ROBERT E., Asst. to Rate Engineer, Brooklyn Edison Co., Inc., 360 Pearl St., Brooklyn, N. Y.
*GIORDMAINA, JOHN N., Electrician, Swift Canadian Co., Ltd., West Toronto; res., Toronto, Ont., Can.
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*GREENSWARD, J. DONALD, Student, Marquette University, Milwaukee; res., Wauwatosa, Wis.
GREGORY, LEWIS JOEL, Foreman, Electric Meter Laboratory, Union Gas & Electric Co., Cincinnati, Ohio.
GRENTE, FERNAND, Chief Engineer of Generation & Transmission, Energia Electrica de Cataluna, Barcelona, Spain.
*GRETTUM, LE ROY A., Electrical Engineer, Wisconsin Railway, Light & Power Co., Winona, Minn.
*GRISCOM, SAMUEL BETTLE, General Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
*GROAT, EDMUND T., Testing Dept., General Electric Co., Schenectady, N. Y.
GROTZINGER, JOHN, Electrical Engineering Dept., Goodyear Tire & Rubber Co., Akron; res., Cuyahoga Falls, Ohio.
GRZYBOWSKI, JOHN MARION, Engg. Lab. & Proc. Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Pittsburgh, Pa.
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HAINES, HENRY H., Station Electrician, So. California Edison Co., Power House No. 2, Big Creek, Calif.
*HAMILTON, SHERMAN, Inspector, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Turtle Creek, Pa.
*HANNA, CLINTON RICHARDS, Research Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.
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WELLS, JOHN T., Asst. Leading Electrical Draftsman, New York Edison Co., 44 E. 23rd St., New York, N. Y.

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WHEELER, BRIAN, Graduate Student, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.
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*WIEGAND, HERMAN H. C., Student, Electrical Engineering Dept., Brooklyn Polytechnic Institute, 85 Livingston St., Brooklyn; res., New York, N. Y.
WILDERMANN, OTTO, Development Work, Engg. Dept., Western Electric Co., Inc., 463 West St., New York, N. Y.: res., Carlstadt, N. J.
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*WOLF, DAVID JOHN, Junior Electrical Engineer, Consumers Power Co., 236 W. Main St., Jackson, Mich.
*WOLF, EZEKIEL, Electrical Engineer & Patent Attorney, Submarine Signal Corp., 160 State St., Boston; res., Dorchester, Mass.
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WOODS, STANLEY K., Inspector, Brooklyn Edison Co., 561 Grand Ave., Brooklyn, N. Y.
WU, TA MU, General Manager, Power Section, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.
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YONEZAWA, YOSOSHICHI, Electrical Engineer, Dept. of Communications, Japan, Mitsui & Co., 65 Broadway, New York, N. Y.
*YOUNG, WILLIAM M., Assistant in Physics University of Illinois, 110 Physics Bldg., Urbana; res., Champaign, Ill.
ZEHR, GEORGE ANDREW, Electrical Engineering Assistant, The Niagara Falls Power Co., Niagara Falls, N. Y.
*ZUELOW, FELIX WILLIAM, Test Course, General Electric Co., Schenectady, N. Y.

Total 446

*Formerly Enrolled Students.

ASSOCIATES REELECTED FEBRUARY 7, 1924

BROWN, CLARENCE C., Fundamental Plan Engineer, The Bell Telephone Co. of Penna., 261 N. Broad St., Philadelphia, Pa.
BROWN, CHRISTIAN EDWARD, Electrical Designer, Public Service Production Co., 80 Park Place, Newark, N. J.
HOCKLEY, WILLIAM, Engineering Dept., British Columbia Electric Railway Co., Vancouver, B. C., Can.
LINDELL, ARTHUR GEORGE, Foreman, Armature Dept., Goodman Mfg. Co., 4834 Halsted St., Chicago, Ill.
VAN WYCK, JAMES R., Electrical Engineer, Viele, Blackwell & Buck, 49 Wall St., New York; res., Brooklyn, N. Y.

MEMBER REELECTED FEBRUARY 7, 1924

IVANOWSKI, GEORGE E., c/o Polish Mechanics Co., Inc., 46 Marszalkowska St., Warsaw, Poland

MEMBERS ELECTED FEBRUARY 7, 1924

BUCHER, GEORGE H., Asst. General Manager, Westinghouse Electric International Co., 165 Broadway, New York, N. Y.
CARLSON, ALFRED, Works Engineer, Singer Mfg. Co., Truman, Ark; for mail, Memphis, Tenn.
COPELAND, W. GORDON, Electrical Engineer, Illinois Power & Light Corp., 230 S. Clark St., Chicago, Ill.
DODD, MAYNARD, Engineer, Asst. Vice-President, Commercial Cable Co., Engineer, Commercial Cable Co., 253 Broadway, New York, N. Y.
FRAZIER, J. L., Hendrie & Bolthoff M. & S. Co., 1635-17th St., Denver, Colo.
RICHARDS, CHARLES RUSS, President, Lehigh University, Bethlehem, Pa.
SCHROEDER, HENRY, Asst. to Sales Manager, Edison Lamp Works, Harrison, N. J.
WHITE, BYRON ELLSWORTH, Engineer, Utica Gas & Electric Co., 222 Genesee St., Utica, N. Y.

TRANSFERRED TO GRADE OF FELLOW, FEBRUARY 7, 1924

CLARK, WALTER G., Comsulting Engineer, New York, N. Y.
JEFFERIES, ERNEST SMITH, Electrical Engineer, Steel Company of Canada, Ltd., Hamilton, Ont.
JEFFREY, FRASER, Electrical Engineer, Allis-Chalmers Manufacturing Co., Milwaukee, Wis.
STRATTON, SAMUEL W., President, Massachusetts Institute of Technology, Cambridge, Mass.

TRANSFERRED TO GRADE OF MEMBER FEBRUARY 7, 1924

FREDERICK, HALSEY A., Electrical Engineer, Research Department, Western Electric Co. New York, N. Y.
KENNEDY, COLIN B., President, Colin B. Kennedy Corp., St. Louis, Mo.
MOMMO, ERNST J., Laboratory Assistant, Public Service Electric Co., Irvington, N. J.
PURINTON, RALPH B., Electrical Engineer, General Electric Co., Chicago, Ill.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held February 1, 1924, recommended the following members for transfer to the grade of membership indicated. Any objections to these transfers should be filed at once with the Secretary.

To Grade of Fellow

McCANN, WILLIAM R., Electrical Engineer, Stone & Webster, Boston, Mass.
SHEPARD, FRANCIS H., Director of Heavy Traction, Westinghouse Electric & Mfg. Co., New York, N. Y.

To Grade of Member

AHLBORN, GEORGE H., Industrial Engineer, Kansas Gas & Electric Co., Wichita, Kans.
BUTCHER, WILLARD F., Senior Engineer, New York & Queens Electric Light & Power Co., Long Island City, N. Y.
ELLYSON, DOUGLAS W., Station Engineer, Kansas City Power & Light Co., Kansas City, Mo.
VANDERPOLL, JAN A., Assistant Field Engineer, Westinghouse Electric & Mfg. Co., New York, N. Y.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before February 29, 1924.

Alberts, E. G., Bureau of Power & Light, Los Angeles, Calif.
Alford, E. C., Jr., Portland Rwy. Lt. & Pr. Co., Portland, Ore.
Allen, B. G., Lakin-Allen Electric Co., Detroit, Mich.
Allen, M. C., Long-Bell Lumber Co. & Longview Public Serv. Co., Longview, Wash.
Alrich, J. D., General Electric Co., Schenectady, N. Y.
Ames, W. E., Dept. of Street Railways, Detroit, Mich.
Apikian, G., (Member), New York Edison Co., New York, N. Y.
Argabrite, C. C., Interstate Public Service Co., Indianapolis, Ind.
Ashton, L. E., Hydro-Electric Power Commission, Verdun, Montreal, Que.
Badger, H. L., Bell Telephone Co. of Pa., Philadelphia, Pa.
Baumer, H. W., Tech. Exam. of Efficiency, City of Chicago, Chicago, Ill.
Bellows, R., Paulsen Spence Co., New York, N. Y.
Bernhard, F. S., Western Electric Co., Inc., New York, N. Y.
Bergenstrahle, K. I. L., General Electric Co., Schenectady, N. Y.
Blain, R., 7th Corps Area, Signal Corps, U. S. A., Omaha, Neb.
Blee, P. J., General Electric Co., Ft. Wayne, Ind.
Boasen, F. D., Public Service Co. of Oklahoma, Guthrie, Okla.
Borgmann, C., Western Electric Co., Inc., New York, N. Y.
Bowman, C. F., Purdue University, W. Lafayette, Ind.
Breckenridge, W. T., American Tel. & Tel. Co., New York, N. Y.
Brooks, J. W., Pass & Seymour, Inc., Solvay, N. Y.
Brown, B., Bliss Electrical School, Takoma Park, Washington, D. C.
Brown, C. W., Short Hills, N. J.
Brown, J. M., Lehigh Valley Railroad, Sayre, Pa.
Brown, P. L., Radio Business, Riverhead, N. Y.
Brown, R. C., Dept. of Street Railways, Detroit, Mich.
Browne, W. A., Government Printing Office, Washington, D. C.
Burbank, E. W., (Member), Allis-Chalmers Mfg. Co., Dallas, Texas
Burke, A. C., Victor X-Ray Corp., Dallas, Texas
Burns, G. J., Rome Wire Co., Buffalo, N. Y.
Byrd, W. M., Phoenix Utility Co., Memphis, Tenn.
Caldwell, D. K., Bureau of Power & Light, Los Angeles, Calif.
Callahan, E. S., Consolidated Tel. & Tel. Subway Co., New York, N. Y.
Carlson, J. W., Western Electric Co., Inc., New York, N. Y.
Carritt, J. G., Rochester Telephone Corp., Rochester, N. Y.
Chandler, L. F., Teacher, High School, Blythe, Calif.
Chang, P. D., General Electric Co., Schenectady, N. Y.

Charleswood, S. G., Indiana Service Co., Ft. Wayne, Ind.
Chen, Y., Ford Motor Co., Highland Park, Mich.
Chilberg, E. E., General Electric Co., Schenectady, N. Y.
Child, R. L., 640 Eastern Parkway, Brooklyn, N. Y.
Clymer, C. C., General Electric Co., Schenectady, N. Y.
Coan, J., Rocky Mountain Fuel Co., Lafayette, Colo.
Cole, E. R., Acheson Graphite Co., Niagara Falls, N. Y.
Colebrook, H. F., City of Winnipeg Hydro-Elec. System, Winnipeg, Manitoba
Collett, C. D., Victor X-Ray Corp., Dallas, Texas
Conn, J. S., General Electric Co., Pittsfield, Mass.
Connell, H. W., (Member), Consulting Engineer, Baldwinsville, N. Y.
Connolly, W. J., Stone & Webster, Inc., Boston, Mass.
Corson, A. J., General Electric Co., W. Lynn, Mass.
Craig, A. C., Bell Telephone Co. of Pa., Philadelphia, Pa.
Cramer, Oris H., Westinghouse Elec. & Mfg. Co., Chicago, Ill.
Creaser, I., Rolls-Royce Co. of America, Inc., East Springfield, Mass.
Dalton, W. J., Brooklyn Edison Co., Brooklyn, N. Y.
Damrau, E. A., The Okonite Co., Pittsburgh, Pa.
Davidson, A., 10 W. 133rd St., New York, N. Y.
Darst, J. M., (Member), Elec. Vacuum Cleaner Co., Inc., Cleveland, Ohio
Dawson, G. L., Nat'l. Advisory Comm. for Aeronautics, Langley Field, Va.
DeCamp, H., Westinghouse Elec. & Mfg. Co. East Pittsburgh, Pa.
Diener, E. E., Philadelphia Electric Co., Philadelphia, Pa.
Diggs, D. M., (Member), International General Elec. Co., Schenectady, N. Y.
Doble, B. H., Victor X-Ray Corp. of Texas, Dallas, Texas
Dodson, H. I., (Member), Northwestern Bell Tel. Co., Omaha, Neb.
Dow, A. L., Hydro Electric Engineer, Ayer, Mass.
Dudley, H. W., Western Electric Co., New York, N. Y.
Eberle, W. R., Radio Corp. of America, New York, N. Y.
Edward, G. W., (Member), Morganite Brush Co., Inc., New York, N. Y.
Edwards, L. L., Halcomb Steel Co., Syracuse, N. Y.
Elftman, J. D., Public Service Co. of Colorado, Boulder, Colo.
Elliott, W. N., N. Slater Co., Ltd., Hamilton, Ont.
Ellis, D., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Fàris, A. W., Purdue University, W. Lafayette, Ind.
Firth, C. J., Philadelphia Electric Co., Philadelphia, Pa.
Fischer, G. H., Philadelphia Electric Co., Philadelphia, Pa.
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Friedrich E. J., Columbus Railway, Power & Light Co., Columbus, Ohio
Frisbie, H. I., Toltz, King & Day, Inc., St. Paul, Minn.
Gamble, G. P., General Electric Co., Boston, Mass.
Gano, H. S., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Garman, J. C., Oregon State College, Corvallis, Ore.
Gartland, H. F., Ace Motor Corp., Philadelphia, Pa.
Gartner, C. E., Jr., Philadelphia Electric Co., Philadelphia, Pa.
Gaunt, E., New York Edison Co., New York, N. Y.
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Gray, K., Goodman Mfg. Co., Chicago, Ill.
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Greenman, J. I., General Electric Co., Erie, Pa.
Griswold, E. C., General Electric Co., Schenectady, N. Y.
Gross, H. W., Spring Garden Institute, Philadelphia, Pa.
Haga, J., New York Edison Co., New York, N. Y.
Halasey, F. R., Aluminum Ore Co., E. St. Louis, Ill.
Hamer, W. D., Mgr., W. D. Hamer Co., Indianapolis, Ind.
Handy, L., United Electric Light & Power Co., New York, N. Y.
Hanks, A. J., Western Union Telegraph Co., New York, N. Y.
Hansen, C., Jr., The Minneapolis General Electric Co., Minneapolis, Minn.
Hardie, E. R., Western Electric Co., Inc., New York, N. Y.
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Hills, F. G. W., 6 Lytton Blvd., Toronto, Ont.
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Hoy, J. M., West Penn Power Co., Springdale, Pa.
Hoyt, M. A., Gibbs & Hill, New York, N. Y.
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Kelly, O. E., Tennessee Eastman Corp., Kingston, Tenn.
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McRae, M. A., J. D. Wallice & Co., Chicago, Ill.
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Otto, G., Western Electric Co., Inc., New York, N. Y.
Oxehufwud, A. G. F., General Electric Co., Schenectady, N. Y.
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Passage, D. H., General Electric Co., Schenectady, N. Y.

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Pennypacker, R M., Philadelphia Electric Co., Philadelphia, Pa.
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Phillips, N. D. B., (Member), Ferguson-Pailon Co., Ltd., Toronto, Ont.
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Plumer, W. C., General Electric Co., Schenectady, N. Y.
Port, F. H., Grand Rapids Show Case Co., Portland, Ore.
Purcell, H. W., American Tel. & Tel. Co., New York, N. Y.
Reed, H. G., Philadelphia Electric Co., Philadelphia, Pa.
Reilly, W. H., Yale University, New Haven, Conn.
Requardt, G. J., (Member), Norton, Bird & Whitman, Baltimore, Md.
Reth, J. H. F., Jr., Penn. Water & Power Co., Baltimore, Md.
Ritter, H. K., (Member), Ritter Illuminating & Mfg. Co., Ltd., Niagara Falls, N. Y.
Rockett, F. H., Bell Telephone Co. of Pa., Philadelphia, Pa.
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Rogers, J. E., Western Electric Co., Inc., New York, N. Y.
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Roth, V. T., Jr., Philadelphia Electric Co., Philadelphia, Pa.
Ruese, W. H., Kansas Electric Power Co., Emporia, Kansas
Ryan, R. E., Sargent & Lundy, Chicago, Ill.
Salamis, B. C., Canadian General Electric Co., Peterboro, Ont.
Samson, H. W., General Electric Co., Schenectady, N. Y.
Schanbusch, C. F., Century Electric Co., St. Louis, Mo.
Schwantes, P. C., Jr., Western Electric Co., Inc., New York, N. Y.
Sealley, G. L., Philadelphia & Reading Railway Co., Reading, Pa.
Sears, C. N., Indiana Bell Telephone Co., South Bend, Ind.
Shaff, J. E., Erie Lighting Co., Erie, Pa.
Shands, G. K., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Shaner, B. K., Medeira Hill & Co., Frackville, Penn.
Shelton, P., Meter Tester, City of Stillwater, Stillwater, Okla.
Shupe, H. P., Metropolitan Power Co., Middletown, Pa.
Snell, D. S., General Electric Co., Schenectady, N. Y.
Snow, V. A., Ranken School, St. Louis, Mo.
Somers, J. C., Duquesne Light Co., Pittsburgh, Pa.
Sommer, P. H., West Virginia Utilities Co., Morgantown, West Va.
Spears, E. L., Spears Electric Service Co., Darlington, S. C.
Speers, J. C., R. D. Speers Co., Davenport, Iowa
Stafford, J. K., Rensselaer Polytechnic Institute, Troy, N. Y.
Stahley, E. P., Drexel Institute, Philadelphia, Pa.
Stauffer, J. H., Craig Electric Co., Pittsburgh, Pa.
Stearns, H. R., Dept. of Street Railways, Detroit, Mich.
Stecker, G. F., Consumers Power Co., Jackson, Mich.
Stein, A., Jr., (Member), General Electric Co., Schenectady, N. Y.
Stein, W. C., Cliffside Park Press, Inc., Grantwood, N. J.
Stevenson, W. C., Bureau of Power & Light, Los Angeles, Calif.
Stolworthy, F. H., New York Edison Co., New York, N. Y.
Strattner, F., Philadelphia Electric Co., Philadelphia, Pa.
Stream, C. C., Kansas City Power & Light Co., Kansas City, Mo.
Strobel, C. K., Union Switch & Signal Co., Swissvale, Pa.
Struth, C. H., Western Electric Co., Inc., New York, N. Y.
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Tarpley, H. I., Pennsylvania State College, State College, Pa.
Thomas, S. A., Rome Wire Co., Buffalo, N. Y.
Usselman, G. L., Radio Corp. of America, Marion, Mass.
Vacha, F., Constructor, 540 W. 122nd St., New York, N. Y.
Vallen, E. J., E. J. Vallen Electrical Co., Akron, Ohio
Van Inwegen, L. C., Public Service Electric Co., of N. J., Red Bank, N. J.
Van Pelt, A. A., B. A. Wesche Electric Co., Cincinnati, Ohio
Verdin, F. E., Schiefer Electric Co., Syracuse, N. Y.
Wainman, F. H., New York Edison Co., New York, N. Y.
Waters, F. N., City Ice Works, Salem, Ore.
Waters, J. I., American Electrical Works, Phillipsdale, R. I.
Welsh, M. G., Citizens Gas Co., Stroudsburg, Pa.
West, H. B., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Wetherbee, C. P., Bell Telephone Co. of Pa., Philadelphia, Pa.
Wilke, H. W., General Electric Co., Atlanta, Ga.
Whitton, L. W., Otis Elevator Co., San Francisco, Calif.
Wickstrand, A. W., Public Service Production Co., Newark, N. J.
Wulff, A. C., Brooklyn Edison Co., Brooklyn, N. Y.
Young, F. C., Stromberg-Carlson Tel. Mfg. Co., Rochester, N. Y.
Young, S. S., Star Electric Co., Coffeyville, Kansas

Total 255.

Foreign

Brent, H. C.,(Member), New Zealand Gov't. Post & Tel. Dept., Wellington, N. Z.
Burns, G. A., Radio Corp. of America, Koko Head, Honolulu, T. H.
Erikson, P. E., (Fellow), International Western Elec. Co., Aldwych, London, W. C. 2, Eng.
Goodman, J. M., Westinghouse Electric Co., Ltd., Johannesburg, S. A.
Korinek, B., Ceskomoravska-Kolben Co., Prague-Vsocany, Czechoslovakia, Europe
Marchand, R. J., Brown, Boveri & Co., Belfort, France
McLeod, N. G., (Member), Gauvain & McLeod, Auckland, N. Z.
Norris, E. D. T., Ferranti, Ltd., Hollinwood, Lancashire, Eng.
Tullio, M., Societa Napoletana per Imprese Elettriche, Napoli, Italy
Walter, C. L., Municipal Electricity Dept., Christchurch, N. Z.
Yosugi, K., Yokohama Electric Wire Works, Yokohama, Japan

Total 11.

STUDENTS ENROLLED FEBRUARY 7, 1924

18520 Patten, Emerson K., Mass. Inst. of Tech.
18521 North, Charles S., Rhode Island State Coll.
18522 Lebourveau, Homer B., Univ. of Alberta
18523 McMurran, Marshall J., Univ. of Wis.
18524 Wiseman, Elmer G., Univ. of Nebraska
18525 Boyle, Norman T., Villanova College
18526 Porter, Donald L., Univ. of Colorado
18527 Oliver, Thomas L., Virginia Poly. Inst.
18528 Stine, Charles F., Univ. of Colorado
18529 Young, Ben H., Engineering School of Milwaukee
18530 Dees, Alfred F., Engineering School of Mil.
18531 Peck, William G., Engg. School of Mil.
18532 Jones, Kenneth B., Univ. of Southern California
18533 Williams, Howard S., Ohio State Univ.
18534 White, Charles B., Jr., Univ. of Nevada
18535 McKinley, Monroe K., State Univ. of New Mexico
18536 Hauck, Vernon D., Univ. of North Dakota
18537 Ekvall, Harold N., Univ. of Pennsylvania
18538 Garrett, Elmer E., Jr., Univ. of Penna.
18539 Hurff, Edgar W., Univ. of Pennsylvania
18540 Kalman, Karl S., Univ. of Pennsylvania
18541 Keane, Robert L., Univ. of Pennsylvania
18542 Mills, Robert L., Univ. of Pennsylvania
18543 Osborn, Robert R., Univ. of Pennsylvania
18544 Powers, George C., Jr., Univ. of Penna.
18545 Warren, Leslie A., Univ. of Pennsylvania
18546 Willink, Arthur, Univ. of Pennsylvania
18547 Mulford, Virgil A., Columbia University
18548 Roberson, Ray R., University of Wash.
18549 Booker, Paul E., University of Wash.
18550 Hottinger, George L., Armour Inst. of Technology
18551 Fleischer, Joseph, Armour Inst. of Tech.
18552 Woodworth, Jack L., Univ. of Idaho
18553 Volgovskoy, Boris V., Univ. of Cincinnati
18554 Fowler, Ralph W., Univ. of Cincinnati
18555 McCane, Ames, Univ. of Washington
18556 Frank, John A., Univ. of Washington
18557 Cutler, Denzil A., Univ. of Washington
18558 McGrath, Leo C., University of Colorado
18559 Cummings, Earl R., Univ. of Colorado
18560 Wollaston, Frank, Univ. of Washington
18561 James, Ruel L., Univ. of Maine
18562 Seago, John A., Clemson Agri. College
18563 McGrew, Clinton J., Clemson Agri. Coll.
18564 Gartner, Irl C., Univ. of Wisconsin
18565 Lee, S. Dwight, Texas A. & M. College
18566 Capel, Albert J., University of Toronto
18567 Replogle, Delbert E., Mass. Inst. of Tech.
18568 Gagliardi, Giocondo, Mass. Inst. of Tech.
18569 Glenn, William E., Alabama Poly. Inst.
18570 Hansen, Lloyd D., Montana State College
18571 Ferris, Fred S., Northeastern University
18572 Patterson, Joseph C., Jr., Montana State College
18573 Miller, William H., Univ. of Toronto
18574 Robinson, Wilford A., Univ. of Utah
18575 Chang, Waken, Cornell University
18576 Tarzian, Sarkes, Univ. of Pennsylvania
18577 Moss, Louis, Univ. of Pennsylvania
18578 Wesnefsky, Jacob, Univ. of Pennsylvania
18579 Fox, Joseph M., Jr., Univ. of Pennsylvania
18580 Emling, John W., Univ. of Pennsylvania
18581 Goldberg, Michael, Univ. of Pennsylvania
18582 Shoemaker, Russell R., Drexel Institute
18583 Hatfield, Samuel J., Mass. Inst. of Tech.
18584 Davis, Frederick R. J., Univ. of Toronto
18585 Grenzebach, Sylvester L., Univ. of Toronto
18586 Archibald, Thomas A., Univ. of Toronto
18587 Campbell, Lorne D., Univ. of Toronto
18588 Baxter, Lawrence H., Univ. of Toronto
18589 Petho, John A., Drexel Institute
18590 Yuan, Harold H., Worcester Poly. Inst.
18591 Craven, William D., Penna. State Coll.
18592 Welch, John E., Northeastern Univ.
18593 Alexander, Harold O., Penna. State Coll.
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DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies.

Indicating Instruments.—Booklet C 1664, 24 pp., "Indicating Instruments for Direct and Alternating Currents." Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

Switchboards.—Bulletin 25, 16 pp. Describes "Bull Dog" Super Safety Switchboards, industrial type, Model Dead Front 5. Mutual Electric & Machine Company, Detroit, Mich.

Line Materials.—Catalog 24, 240 pp. A comprehensive, loose-leaf catalog, with binder, describing transmission and distribution line materials, including street fixtures and accessories and primary and secondary fuses. Line Material Company, South Milwaukee, Wis.

Electrical Porcelains.—Booklet, 16 pp., "Judging One by the Company He Keeps." Illustrates the porcelain parts furnished to a number of prominent users in the electrical industry. The R. Thomas & Sons Company, East Liverpool, O.

D. C. Transformer.—Folder, 4 pp. Describes a transformer for reducing direct current from commercial lighting circuits to low-voltage direct current, to be used for operating annunciators, elevatoı signals, alarms, etc. Gisholt Machine Company, Madison, Wis.

Electric Railways.—Booklet, 54 pp., "A Brief Outline of the Development and Progress of the Electric Railway Industry." The book sets forth the history of the electric railway industry and is profusely illustrated. It describes the equipment and service of the company available in this field. Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

Meter Testing Devices.—Bulletin 728 describes blocks for testing self-contained meters without interruption to consumer service. Bulletin 940 describes switches for testing meters. Bulletin A10 describes metal meter devices designed for use in conjunction with testing switches and blocks manufactured by the company. The Superior Switchboard & Devices Company, Canton, Ohio.

NOTES OF THE INDUSTRY

The Ohio Brass Company recently purchased approximately five acres of land and buildings just across the Pennsylvania Railroad tracks from its present Mansfield, Ohio, plant. The tract is triangular in shape and is bounded by three trunk-line railroads, the Pennsylvania, Erie, and Baltimore & Ohio. The purchase was made from the Aultman-Taylor Machinery Company.

Killark Electric Manufacturing Company, St. Louis, Mo.—Three new sales agencies have been established as follows: E. G. Hohs, 155 Colbeck St., Toronto, Ont., Canada, has been appointed sales agent in the province of Ontario. G. L. MacGillivray & Co., Ltd., 3 St Nicholas St., Montreal, Que., Canada, have been appointed sales agen s in the provinces of Quebec, New Brunswick and Nova Scotia, and George G. Young & Company, Bourse Building, Philadelphia, have been appointed sales agents in eastern Pennsylvania, southern New Jersey and Delaware.

Russian Order for Farm Power Plants.—The Russian Soviet Government has ordered from the Westinghouse Electric & Manufacturing Company through the Allied American Corporation, five sample E-63, 1500 watt, 110-volt, self-contained lighting and power plants. The plants will be used in the richest agricultural district in Southeast Russia, to which district the Allied American Corporation has already shipped 800 Fordson Tractors. This is a trial order to be followed by another for several hundred more plants if the first are satisfactory.

Large Circuit Breaker Order.—An order for oil circuit breakers was recently placed with the General Electric Company by the Public Service Production Company of New Jersey, covering 27 type FHK-130 triple-pole, single-throw, 15,000-volt, 3000 ampere solenoid operated, isolated phase units. These are to be furnished with necessary gang-operated disconnecting switches. The equipment will be installed in a station at New Kearny, N. J. The various phases will be mounted vertically. This vertical isolated phase arrangement is being adopted by many of the large central stations. The oil circuit breakers have an interrupting capacity of one million and a half kv-a.

New Power Plant for Columbus Public Utility.—The Columbus Railway Power & Light Company is planning the erection of a new 150,000-kilowatt station to be installed about ten miles from Columbus, Ohio. This station will supply power for railway, lighting and industrial purposes to the immediate district, and is laid out for five 30,000-kilowatt turbine generator sets, two of which have been ordered from the General Electric Company. In addition to this equipment, the General Electric Company will also furnish seven 12,500 kv-a. self-cooled transformers and complete switchboard of the benchboard type of construction.

The Packard Electric Company, Warren, O., expect to begin operations on March 1, in a new plant, which has been built for manufacturing transformers and which will practically quadruple its previous capacity. All of the activities of the transformer division will be confined to this plant. The old plant will be remodeled and given over entirely to the manufacture of Packard automotive cables. The transformer line includes a complete range of distribution transformers, power transformers up to 10,000 kv-a. capacity, weatherproof metering transformers, and in addition, transformers for all special applications such as furnace work, refrigerating service, etc.

The Mutual Electric & Machine Company, Detroit, Michigan, manufacturers of "Bull Dog" safety switches, switchboards, and panelboards, announce the purchase of the plant of the Aluminum Castings Company. This property faces 500 feet on Joseph Campau Avenue, adjacent to Dodge Bros. plant, and is 860 feet in depth. It comprises about eight acres, four acres under roof, one-story, fire-proof construction, and has ample siding facilities. The Mutual Company plans to vacate its two present plants at once and move its entire organization and equipment into the new factory. Increased space, and better manufacturing and shipping facilities will enable the company greatly to increase its production of electrical equipment, which is widely distributed in this and other countries. The officers of the Mutual Electric & Machine Company are H. J. L. Frank, President; Leon H. Frank, Secretary; F. M. Ferguson, Treasurer.

Western Electric Company, New York.—A number of contracts have been let for materials and their installation in the several units of the Western Electric telephone, switchboard and cable works, now under construction on the company's 60-acre tract at Kearny, N. J. The new contracts amount to about $60,000 for furnishing and installing transmission cable conduit and fiber duct systems, electric light conduit and wiring system, etc., have been awarded to J. P. Hall-Smith, New York City. Almirall & Company, New York City, will furnish and install the forced hot water system, exhaust system, piping supports and pressure blower systems for the cable buildings at a cost of about $91,000. The Turner Construction Company has been awarded contracts totaling about $80,000 for materials and installation.

The cable buildings, which are a part of the works, where ultimately 30,000 men and women will be employed, will be completed and put in operation this fall.